New Scientist

WEEKLY 9 April 2022

THE SPREAD OF BAD SCIENCE AND HOW TO STOP IT

UNCRACKABLE ENCRYPTION

THE RISE OF THE DELTACRON VARIANT

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Entries for the 2022 Ryman Prize close at 5pm on Friday, July 15, 2022 (New Zealand time).

Go to **rymanprize.com** for more information.

This week's issue

On the cover

40 Stepping into the Stone Age
How fossil footprints are revealing the secret lives of our ancestors

New Scientist

STEPPING INTO THE STONE AGE

Vol 254 No 3381
Cover image: Simon Prades

45 The spread of bad science and how to stop it

36 Uncrackable encryption

15 The rise of the deltacron variant

7 Three years left to keep 1.5°C climate goal alive

14 Covid's toll on UK hospitals
17 Magnetic slime robot
10 Calculating your Alzheimer's risk
23 The volcanoes on Pluto

40 Features

> "Children were splashing in the muddy puddles left in the sloth footprints"

News

12 Quantum flash
The strange reason popping bubbles give off light

19 Java Man
Unpublished clues from a historic archaeological dig

20 Lawless Amazon
How Brazil's president has weakened protections for the rainforest

Views

25 Comment
How helpful are tech alternatives to therapy, asks Eleanor Morgan

27 The columnist
Focus on plant loss more, says Beronda L. Montgomery

28 Aperture
Earth's strange arteries

30 Letters
Dealing with coughs and sneezes isn't always easy

32 Culture
An intriguing look at the role of luck in our lives

DOUG GIMESY/NATUREPL

9 Rewinding evolution Genomes of extinct ancestors reconstructed

Features

36 Extreme encryption
Could a clever form of cryptography allow us to see data without ever looking at it?

40 Lost footprints
Fossilised tracks provide a window into the emotional lives of our Stone Age ancestors

45 Failure to replicate
Bad science is spreading – how do we fix the problem?

The back pages

51 Citizen science
Unlock the secrets of letters

53 Puzzles
Try our crossword, quick quiz and logic puzzle

54 *Almost* the last word
Why does some music evoke certain emotions?

55 Tom Gauld for *New Scientist*
A cartoonist's take on the world

56 Feedback
Quantum hairdos and mattress turning: the week in weird

Elsewhere on New Scientist

Academy

The science of your well-being

Does being healthier actually make us happier? This course considers the way that the interactions of mind, body, diet and exercise affect our lives, for better or for worse. Leading experts will explain how we can change our habits and how food and exercise influence our physical and mental health, and debunk many myths about the well-being industry along the way.

academy.newscientist.com

Event

Physics at the end of the universe

The big bang theory tells the story of the beginning of the universe. But how does that story end? Join astrophysicist Katie Mack as she tells us about the ultimate fate of our cosmic home, and what the catastrophic destruction of all reality would look like to anyone still around to see it. Watch online at 6pm BST on 28 April. Also available on demand.

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Podcast

Weekly

The team discuss a world-first gene therapy used to treat a rare skin disease often called "the worst disease you have never heard of". They also explain the implications of detecting the most distant individual star that we have ever seen. Plus, listen to the aquatic sounds of Monterey Bay, California, in an escapist audio quiz.

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Listen carefully Hear the aquatic sounds of Monterey Bay, California

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Well-being revelations Discover the secrets of health and happiness

Video

Slime robot

Head over to our YouTube channel to watch a robot made of magnetic slime navigate narrow passages, grasp objects and fix broken circuits. The slimy robot's custard-like consistency and silicon-coated body could one day make it safe enough to deploy in humans to perform tasks such as retrieving objects swallowed by accident.

youtube.com/newscientist

Newsletter

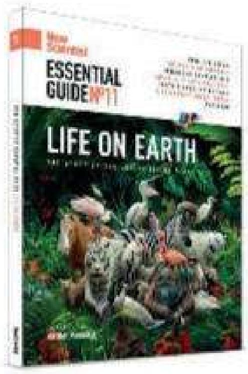
Fix the Planet

Chief reporter Adam Vaughan explores the launch of Destination Earth – a €140 million project to build digital, interactive replicas of the planet that will allow everyone from scientists to energy companies to explore the impacts of climate change and how we adapt to them.

newscientist.com/fix-the-planet

Podcast

> **"One whale is worth $2 million in terms of its carbon drawdown value"**



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A lasting imprint

Ancient footprints give a wonderful insight into our ancestors' personal lives

IT WAS out in the desert of New Mexico that humanity first tested the atomic bomb, creating an explosion that left an indelible imprint on our planet. In the same area, just a few dozen kilometres south, scientists are now finding imprints of quite a different sort: human footprints from the Stone Age. These tracks don't have anything like the historical significance of the first nuclear test – and that is precisely why they are so important.

Archaeology often focuses on the big picture: technological shifts, epic migrations, the fall of civilisations. By contrast, the stones and bones we dig up rarely provide a clear sense of what everyday life was like for ordinary people, especially when it comes to the earliest humans, of whom there is precious little archaeological evidence anyway.

The footprints being discovered in White Sands National Park, New Mexico, are the perfect counterpoint to this problem. Archaeologists had barely bothered to look for fossil footprints for decades, assuming them to be vanishingly rare. But as we report on page 40, this particular site is giving the lie to that.

> "The stones and bones we dig up rarely tell us what everyday life was like for ordinary people"

The landscape at White Sands is strewn with ancient human tracks. What's more, analysing details like the size and spacing of the footprints allows us to recreate snippets of people's lives. The stories are incredible, from the thrill of hunting a giant ground sloth to the moments of joy as ancient children splash in muddy puddles. No other archaeological resource can give us these kinds of insights.

It is about time that we started more actively searching for ancient human prints in other places. It is likely that they can be found at many other sites around the world, and it will be fascinating to see what more can be unearthed.

There is, however, a danger here of pushing the evidence too far in pursuit of a good yarn. We can reconstruct the cut and thrust of an animal hunt, but we must be careful not to assume we know how the hunters actually felt. Get this right, though, and footprints are set to leave a lasting imprint on our understanding of our ancient human ancestors. ▮

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Tropical style
Birds that live near the equator are more colourful **p10**

Air quality crisis
Harmful pollution affects 99 per cent of people **p12**

Flawed climate plan
EU proposals don't account for land footprint **p16**

Total recall
Bats remember sounds they heard years ago **p17**

Bird brains
A type of neuron may explain crows' intelligence **p19**

A large wind farm in Palm Springs, California

ROBERT ALEXANDER/GETTY IMAGES

Climate change

Urgent climate warning

UN panel says the world must make rapid, deep cuts to emissions to hold off extreme climate change, reports **Adam Vaughan**

GREENHOUSE gas emissions must peak within three years to hold global warming to 1.5°C, according to the latest research from the Intergovernmental Panel on Climate Change (IPCC).

In a report on how countries can tackle the climate crisis, published on 4 April, the IPCC warned that the window for staving off highly dangerous warming has shrunk drastically due to past failures to act. It found that the world can afford to emit just 500 gigatonnes of carbon dioxide from 2020 onwards for a 50 per cent chance of holding temperature rises to 1.5°C.

Scenarios modelling how to meet that tight "carbon budget" require emissions to peak by 2025, before falling 43 per cent by 2030 on 2019 levels. That would require a gargantuan effort, given global emissions rose by a record 5.5 per cent in 2021. Many governments are also preoccupied with the war in Ukraine and the coronavirus pandemic, and some are mulling extra oil and gas production.

Coal use must drop by 95 per cent by 2050 on 2019 levels, oil by 60 per cent and gas by 45 per cent to meet the 1.5°C goal, figures that Jan Christoph Minx, one of the authors of the report, said are "very striking". Even meeting the Paris Agreement's weaker target of 2°C would leave "a substantial amount of fossil fuels unburned" and render up to $4 trillion of fossil fuel infrastructure "stranded". "We need to end the age of fossil fuels," said Minx, speaking at a press briefing.

The report says governments aren't doing enough yet. Tallying pledges made before last year's COP26 climate summit, the world will "likely exceed" 1.5°C this century, a vital threshold for avoiding the most extreme effects. "[The report] is a file of shame, cataloguing the empty pledges that put us firmly on track towards an unlivable world," said Antonio Guterres at the UN in a statement.

> **"The report catalogues the empty pledges that put us on track towards an unlivable world"**

Yet, the IPCC found reasons for hope. At least 18 countries have managed continued emissions cuts for more than a decade, while the costs of key technologies for decarbonisation plummeted between 2010 and 2019.

"Rapid and deep" reductions will be needed across all sectors, using a mix of renewable energy, carbon capture and storage (CCS), lower energy demand, better energy efficiency and a huge ramp-up of ways to remove CO_2 from the atmosphere, such as direct air capture machines, says the report. CCS use was found to be "far below" the amount needed to reach climate goals.

For the first time, the IPCC also considered the role of behavioural change on emissions reductions, such as shifting diets. "The way we move around, the way we eat, the way we generate energy, everything needs to change," says Pete Smith, an IPCC author.

Despite claims in some quarters that cutting emissions will be too expensive, the IPCC says that mitigation costs for meeting the 2°C target would be "small" compared with global GDP growth, and would be 1.3 to 2.7 per cent lower in 2050 than in a business-as-usual world.

The report is the third of four that make up the IPCC's "sixth assessment report": the first was on the causes of climate change; the second on the impacts. The new report was signed off after an approval session that saw the launch postponed by 6 hours. The delay was due to Saudi Arabia's requests around language on long-term fossil fuel use, India's views on carbon budgets and future economic growth, and a row between the US and China over financing to act on climate change, delegates told *New Scientist*. ▮

Analysis Climate change

1.5°C goal is barely still in reach

The IPCC's report shows we have the tools to make fast cuts in emissions. But there is little sign of the political will to act now, says **Adam Vaughan**

THE message is very clear. In three instalments, the Intergovernmental Panel on Climate Change (IPCC) has told us that humans are "unequivocally" to blame for rising temperatures, we are outstripping our ability to adapt and, on 4 April, that we can fix this crisis. The fix requires us to ensure that global greenhouse gas emissions peak in three years and are cut by 43 per cent by 2030. Achieve that, and we have a 50 per cent chance of staying under 1.5°C of global warming, the threshold for when climate impacts become far more damaging.

Yet, as the IPCC itself points out, without stronger policies from governments, global emissions are projected to keep rising beyond 2025. The current trajectory is for a planet that has warmed by a hellish 3.2°C. So what reasons are there to think the world can land at 1.5°C instead?

There is no good historical precedent for such rapid and deep emissions reductions. Global emissions were just under 60 gigatonnes of carbon dioxide equivalents in 2019, after factoring in everything from fossil fuel burning to land use changes such as forests cleared for farms.

"We're not talking about business as usual if we are to address the challenge of climate change"

Emissions have grown despite years of UN climate talks and swift deployment of renewable energy projects. The rate has slowed, though: average annual growth was 1.3 per cent between 2010 and 2019; it was 2.1 per cent in the decade before. Yet reaching a plateau remains elusive. Covid-19 restrictions delivered a record fall in fossil fuel emissions in 2020, but a coal-fuelled rebound in 2021 wiped out those savings. Emissions are expected to rise this year too.

IAN HITCHCOCK/GETTY IMAGES

Severe flooding in Townsville, Australia, in February 2019

The world missed a chance to restructure its energy and transport systems with pandemic stimulus packages. The current energy crisis, exacerbated by Russia's invasion of Ukraine, presents another possible inflection point.

Jim Skea, co-chair of the IPCC's working group III, which produced this week's report, says scientists are conscious that getting emissions to peak by 2025 and almost halve by 2030 represents a "big change of direction". However, he adds: "What the report absolutely makes clear is that we're not talking about business as usual if we are going to address the challenge of climate change. So we don't look at the immediate past and say we expect that pattern to continue."

The report offers a bounty of ways to avoid business continuing as usual for emissions. Wind and solar power have the greatest potential when it comes to making cuts, with nuclear offering a much smaller supporting role. Meanwhile, we must switch from fossil fuels to electrification to heat buildings and power cars, scale up alternative fuels including hydrogen, improve energy efficiency and implement carbon capture and storage in sectors such as heavy industry.

Reducing emissions isn't just about technological fixes. "Demand-side strategies" – behaviour changes such as switching to more plant-based diets and flying less – could cut emissions by between 40 and 70 per cent in all sectors by 2050. Among the 60 actions that individuals could take to curb consumption, walking and cycling are identified as offering the biggest potential emissions reduction.

The IPCC also hints that the richest in society could deliver the biggest emissions cuts, if people curbed their consumption of goods and services. The 10 per cent of households worldwide with the highest per capita emissions are responsible for 45 per cent of all consumption-based household emissions.

No time to lose

The good news is that in a world where money talks, many of the measures needed are cheaper than the cost of not acting. Both the main types of solar power, plus onshore and offshore wind power, are already at costs that compete with fossil fuels in many places, says the report. The prices of key technologies have plummeted, such as the cost per kilowatt-hour for lithium-ion batteries falling by 85 per cent between 2010 and 2019.

The IPCC makes clear that there is still technically a path to the safer haven of a 1.5°C world. But there is little sign of the political will to embark on that trail. Last year, 196 countries promised to "revisit and strengthen" their national climate plans in 2022. To date, none has. Scientists are usually reluctant to say when the totemic 1.5°C target will be out of reach. But Skea admits that it will be "gone" if more ambitious plans don't arrive before the next UN climate summit, in Egypt this November.

Time is almost up. Skea insists that making sure emissions peak within three years is still feasible, but as he tells *New Scientist*: "The longer we put off action, in terms of addressing climate change, the bigger the feasibility challenges will be." ■

Evolution

Genomes of extinct species revealed by massive analysis of living organisms

Michael Le Page

THE genomes of more than 600 plants, animals and fungi that went extinct tens or even hundreds of millions of years ago, leaving no physical trace on Earth, have been partially reconstructed by rewinding the evolutionary history of their living descendants. This has given us the best pictures so far of the genomes of various distant ancestors of humans, from the ancestor of monkeys and apes all the way back to the ancestor of the first amphibians and of all vertebrates.

Almost all that we know about past life comes from fossils. As important as they are, most fossil species aren't the direct ancestors of the organisms alive today. For instance, almost all dinosaurs died out, with just one branch surviving in the form of birds.

"It's not easy to connect a fossil to modern species, because you don't know where it is in the tree of life," says Hugues Roest Crollius at the École Normale Supérieure in Paris.

Unlike fossils, however, the genomes of living creatures give us a direct link to their ancestors, he says. Genomes are a record of evolutionary history going back to the dawn of life. And by comparing the genomes of two or more related species, it is possible to effectively rewind those historical changes to work out the genome of a shared ancestor.

Biologists have been doing this ever since the genomes of different species started to become available. In 2017, for instance, Denis Larkin at the Royal Veterinary College, University of London, and his colleagues used a computer algorithm to partially reconstruct the genomes of seven ancestors of humans, including the ancestor of a group called Boreoeutheria that contains most placental mammals, and which lived around 95 million years ago.

Since then, the genomes of thousands more species have been sequenced. This means ancestral genomes can be reconstructed more accurately, but it also poses a challenge in terms of the amount of processing power required. So Roest Crollius and his colleagues have developed a streamlined algorithm that works out which genes an ancestor had and the order in which they were arranged along chromosomes.

Because more genomes are available and the algorithm is so fast, Roest Crollius's team has been able to reconstruct hundreds of ancestral genomes. They include the 45-million-year-old ancestor of monkeys and apes including us, the 50-million-year-old ancestor of grasses and the 102-million-year-old ancestor of placental mammals including elephants. The team even reconstructed the ancestor of all vertebrates and of all tetrapods (amphibians and their descendants), but these ancient genomes are incomplete and fragmentary (bioRxiv, doi.org/hpdk).

The researchers say their reconstructions closely match previous ones where they exist, but are more complete. "Our approach does reconstructions more accurately and with greater resolution, and also it goes further back in time," says Roest Crollius.

Many other ancestral genomes have never been reconstructed before. These include the ancestor of lemurs, bushbabies and lorises, and the ancestor of bats.

With even more genomes and processing power, it may become possible to work out the genetic code of ancestral genes. But reconstructing the sequence of the non-coding DNA between genes isn't feasible, says Roest Crollius, as it changes too fast.

"Nobody will be able to go back very far in time reconstructing entire genomes," he says.

In most species, much of this non-coding DNA is junk, consisting of thousands of mutated copies of genetic parasites known as transposons. But some non-coding DNA helps regulate gene activities and plays an important role in evolution – and without this regulatory DNA, it will be impossible to resurrect extinct species, says Roest Crollius. ▮

SHUTTERSTOCK

Elephants, bats, lemurs and frogs are just some of the organisms analysed

Could we bring back extinct species?

Ancestral genomes could help efforts to resurrect species such as the woolly mammoth.

Several groups hope to create animals that resemble extinct species by sequencing the DNA in preserved samples, then editing the genome of a close living relative to make it a good match for the extinct species.

The problem with this approach, says Thomas Gilbert at the University of Copenhagen in Denmark, is that ancient DNA breaks into lots of little pieces. The only way to reassemble them is to use the genome of a living relative as a guide. But both the extinct and living species will have changed since splitting from their common ancestor, so the reassembled ancient genome will have some key parts missing.

In a 2020 study, Gilbert and his colleagues showed that reconstructing the genome of a common ancestor and using that as a guide can improve the accuracy of reassembled ancient genomes.

"If you halve the evolutionary divergence by reconstructing the ancestor, it can improve the amount of data you can reconstruct from your crappy ancient DNA, as you are mapping to a reference that is closer," says Gilbert.

Biology

Songbirds living close to the equator are more colourful

Chen Ly

UNIVERSITY OF SHEFFIELD/NHM TRING/LARA NOURI

TROPICAL regions contain songbirds (pictured) that are more colourful than those living in milder climates.

The idea that life in the tropics is more colourful was first introduced by 19th-century naturalists such as Charles Darwin and Alexander von Humboldt. Until recently, however, it has been hard to prove this hypothesis due to difficulty in quantifying colouration.

Now, equipped with advanced image analysis techniques, researchers led by Chris Cooney at the University of Sheffield, UK, have investigated using songbirds – birds in the group Passeriformes – which comprise around 60 per cent of all bird species.

The researchers created a deep learning AI program to analyse images of birds based on how colourful their plumage was. They defined colourfulness as the "range of colours that are perceptually different from one another". So, a highly colourful bird would be one whose plumage had a diverse variety of colours. The team then input images of more than 24,000 individuals representing 4527 songbird species.

The researchers found that both male and female songbirds that lived close to the equator tended to be more colourful than their temperate counterparts (*Nature Ecology & Evolution*, doi.org/hpd5).

It's "another component of global biodiversity", says Cooney – and documenting it reveals something about the way that biodiversity is distributed across the planet. ▮

Neurology

Genes linked to Alzheimer's could help estimate your risk

Jason Arunn Murugesu

THE biggest Alzheimer's study of its kind has more than doubled the number of genetic variations known to be implicated in the disease. The research points to a future in which people could be given a genetic risk score for their potential to develop the condition and personalised strategies for prevention and treatment.

Alzheimer's is the most common cause of dementia, affecting more than 850,000 people in the UK. About 60 to 80 per cent of the risk for the condition is thought to be due to genetics.

To find more of the genetic factors responsible, Rebecca Sims at Cardiff University in the UK and her colleagues looked at the genomes of more than 100,000 people who had Alzheimer's or had a parent with the condition, and compared them with about 600,000 people with no family history of the disease.

This is much more than the number of people with Alzheimer's analysed by any previous genome-wide association study (GWAS). "The last major GWAS in Alzheimer's had about 22,000 people with Alzheimer's in its initial set-up," says Sims.

The analysis confirmed the role of 33 gene variations that had previously been linked to the disease and added a further 42 specific variations to that list (*Nature Genetics*, doi.org/hpdw).

Sims says no variation seems more significant than any other. "Part of what this study shows is how complex this disease actually is and how multifactorial it is," she says.

75

Gene variations linked to Alzheimer's in the study

But it does highlight the role that microglia – immune cells in the brain – can play in the disease, says Sims. "Years ago, we were only looking at neurons and how they might be involved in Alzheimer's, but now we know that these cells are really important too."

This research will make it easier to ensure people are given the best treatment for them, she says. For example, Alzheimer's in one person may be caused by variations involving microglia, whereas in another it could be due to dysfunctions in fat metabolism.

"A lot of drugs may be more useful in certain people than others depending on what type of pathways are involved," says Sims. "Potentially, the drugs will have a bigger effect if we target the right pathways."

The team found that including these newly discovered gene variations improved the accuracy of genetic risk scores, which could be used to inform people about their potential to develop the disease. "If someone's got a really high risk of developing Alzheimer's, potentially they can start taking drugs earlier in life to help either delay it or even prevent it," says Sims.

"I am incredibly excited by the implications of this study," says Catherine Kaczorowski at the Jackson Laboratory in Bar Harbor, Maine.

One limitation of the study is that nearly all the participants in it were white – in common with many other GWAS. This is by design, because different populations of people will have different genetic variations and so it is harder to compare people with and without a specific disease in a more diverse study group.

Sims says it is unclear to what extent the findings will be applicable to people of colour. "We need this research funded for other populations," she says. ▮

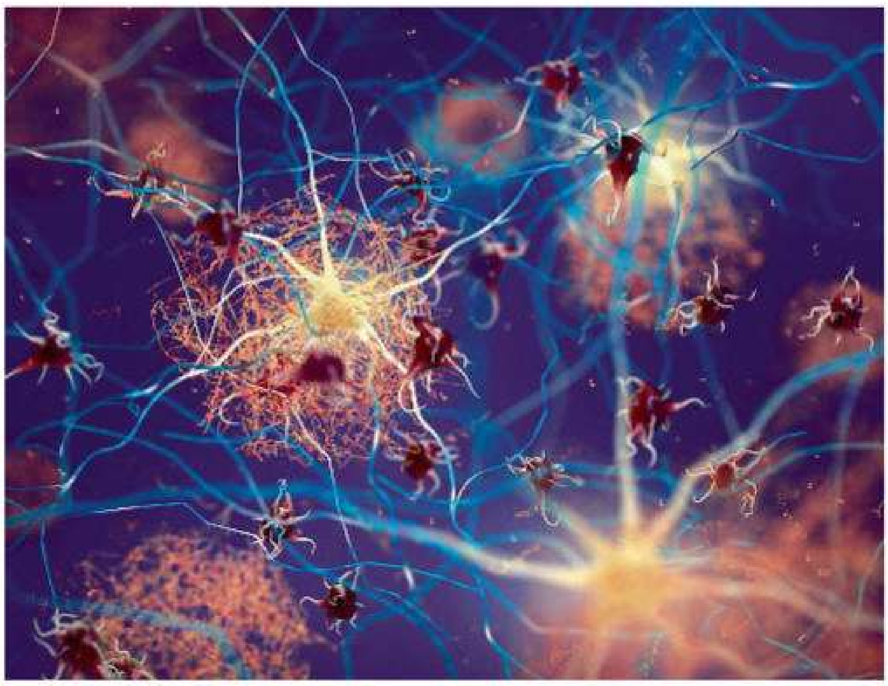
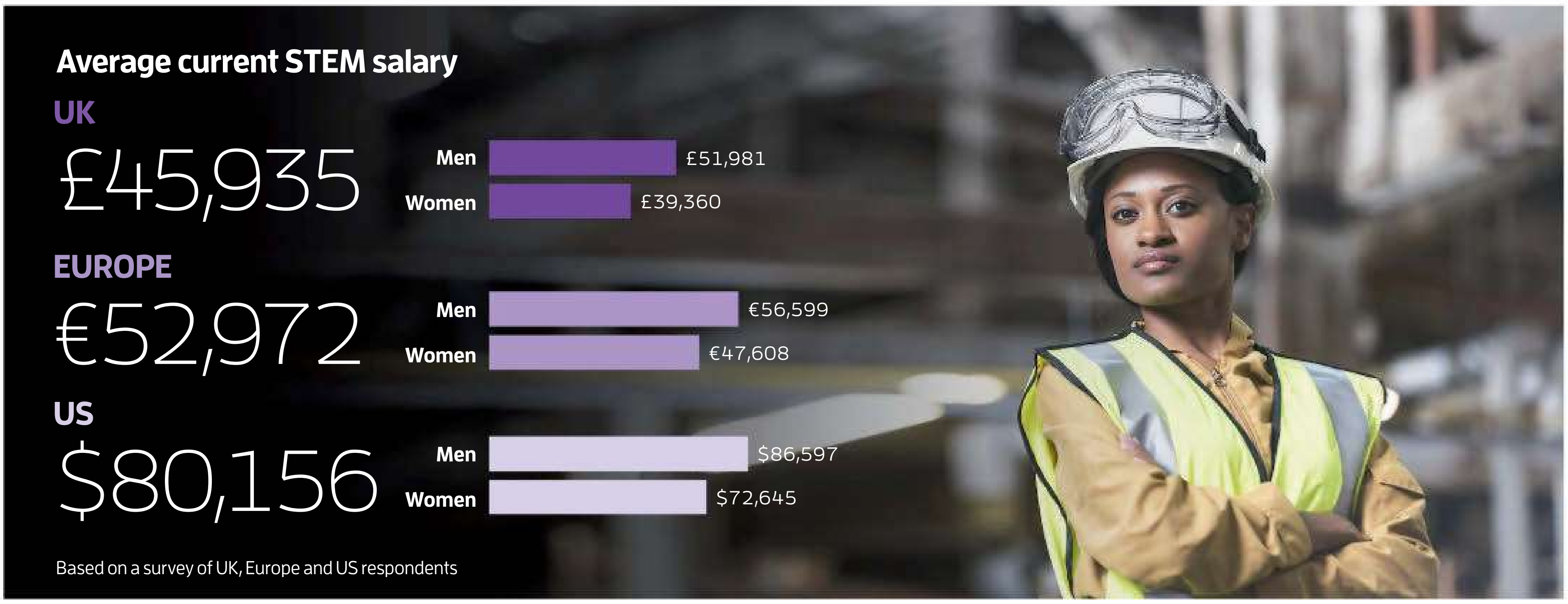

NOBEASTSOFIERCE SCIENCE/ALAMY

Illustration of amyloid plaques in the brain, a feature of Alzheimer's



KALI9/ISTOCK PHOTO

STEM pay gaps worsen

Despite the economic impact of the pandemic, STEM salaries are on the rise – but not for everyone

Salary is one of the first questions on people's lips when considering a potential employer or job, and for STEM it is no different. What are pay prospects like for the industry? How might salary trends be changing? And are there disparities that employers could address to attract and retain employees, and help make the industry more fulfilling for everyone?

These were key questions in the 2022 New Scientist Jobs Global Employment Report in association with science recruitment specialists SRG. This year, the number of respondents reached a record high of more than 4300 people currently working in STEM in the UK, the rest of Europe and the US. In the 2021 survey, covid-19 played a significant role in shaping many aspects of work. Now, more than two years on from the pandemic's onset, employment in STEM seems to have adapted well on the whole, with salaries by region and sector holding up well.

The average annual salary of respondents in the UK was £45,935 – the highest since the survey began – with the majority earning between £20,000 and £29,000 and 6 per cent earning above £100,000. The highest-paid areas were East Anglia, the south-east and Greater London, which have all consistently been top spots for salary. For the rest of Europe, the average wage came to €52,972. This figure is always bumped up by the disproportionately high salaries of those answering from Switzerland, home to the respondents with the highest wages in this region. However, it is still lower than the UK's currency equivalent. In the US, the average salary was $80,156, the only region of the three to see a decrease in earnings. But a substantial 16 per cent of US respondents were earning more than $150,000, with Virginia being the highest-earning state.

Looking to individual sectors, in the UK, engineers earned the most of all those surveyed. They had an average wage of £57,881, more than 25 per cent above the average, which is in agreement with other surveys on pay for the sector. Medical technology, pharmaceuticals and biotechnology also emerged as lucrative UK sectors. At the other end of the scale, clinical and laboratory work had the lowest salary prospects, with earnings falling 23 per cent below the average. In Europe, those in pharmaceuticals had the highest wage overall, in stark contrast to academia, which paid a staggering 32 per cent below the average. Similarly, in the US, the engineering and pharmaceutical sectors came out on top.

Inequalities worsen

Overall, the findings reflect a broadly positive picture for STEM salaries, which seem to be increasing across the regions surveyed. This is reassuring given the economic effects of covid-19, as well as the rising demand for STEM graduates and skills in many countries. But when it comes to salary differences between groups, the results are less savoury.

One key finding of the survey was that the gender pay gap within STEM has significantly widened this year across all regions. It has jumped from 19.4 per cent to almost 28 per cent in the UK; from 7 per cent to 17 per cent in Europe; and from 12 per cent to 17.5 per cent in the US. In the UK, this gap amounts to men earning £6000 above the average and women earning £6600 below, a pay gap increase that is mirrored in the nation overall, albeit not as drastically.

It seems that the pandemic has contributed to this concerning trend. The age groups most likely to be parents of young children had some of the largest gender pay gaps in the survey, suggesting that women may have been taking on more of the increased childcare commitments while schools and nurseries were disrupted by covid-19. Changes to working, such as working from home and furlough, may also have aggravated women's existing under-representation in more senior or highly paid roles so that women's earnings have taken a bigger hit than men's.

And it isn't just women's salaries that are suffering. The survey also revealed that salaries of minority ethnicity groups in the UK were falling short too, with only white respondents earning above the average salary of £45,935. In general, this was linked to job levels – 30 per cent of white respondents held senior positions in their organisation, for example, compared with only 10 per cent of Black respondents, of whom there were none at the highest executive level.

Despite generally good salaries across the industry, then, critical pay gaps remain and are worsening. Actions such as funding schemes to help people return to work, ensuring fair recruitment and changing workplace culture will help to improve pay prospects for marginalised groups and tackle some of the inequalities that are still rife in all industries, including STEM. Salary will always be a hot topic – but it should be for all the right reasons.

Gege Li is a freelance writer based in London. Download the full salary survey at newscientist.com/globalemploymentreport

Physics

Bubbles give off weird light when popped because of quantum physics

Alex Wilkins

WHEN a bubble pops in a liquid, it can produce a flash of light, which we now know is thanks to quantum mechanics.

Sonoluminescence is a phenomenon in which small bubbles, produced and fixed in place by an ultrasound wave in a liquid, collapse and make particles of light, or photons. Physicists have known about this process for decades, but the mechanisms behind it weren't fully known.

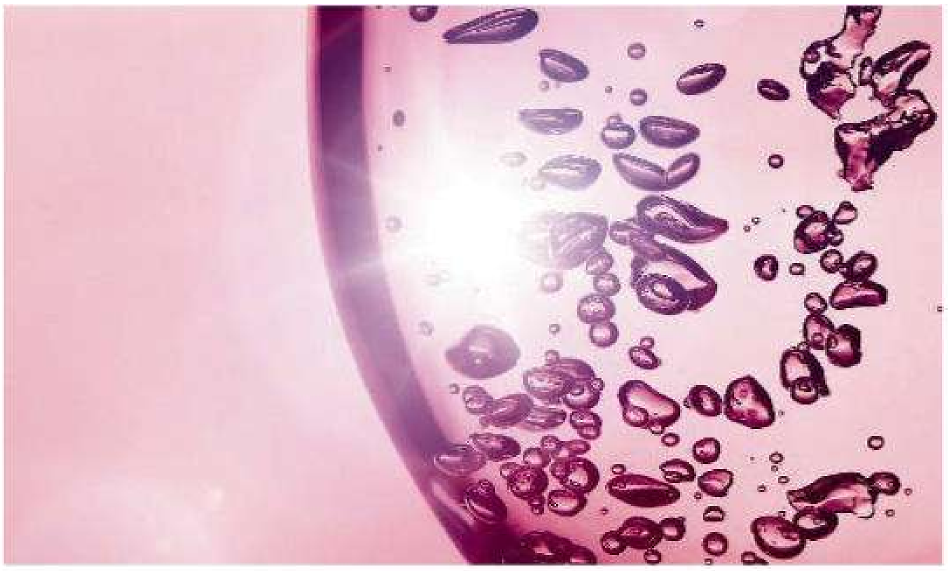
Now, Ebrahim Karimi at the University of Ottawa, Canada, and his colleagues have measured the quantum nature of the photons produced for the first time, showing that the underlying process is quantum mechanical.

Karimi and his team set up a flask filled with water, which contained a single air bubble, and placed seven mirrors around the flask to reflect photons onto a photon-detecting camera. When the bubble was made to collapse, it produced a burst of photons, which they measured sequentially.

In classical light sources, such as a lamp or the sun, photons are generated at random times and arrive at a destination – such as a camera – with no discernible pattern. But quantum processes produce an effect called anti-bunching, where photons arrive with a certain regularity. It is impossible to have anti-bunching if a system is obeying classical physics, says Karimi. "It requires quantum [physics] to be involved."

Karimi and his team used the camera to calculate statistical properties of the photons that are unique to quantum events. "We did this for many different samples during different days with different timing," says Karimi. Doing so confirmed the photons were correlated with one another in a way consistent with quantum processes (arxiv.org/abs/2203.11337).

Bubbles sometimes release flashes of light when they pop



SHUTTERSTOCK/OLEGRI

The experiment, which took the researchers more than five years to complete, was particularly difficult because they didn't know when the incredibly short photon pulse would be produced.

"This is like standing alongside a motorway and having one car a day and trying to find it, not knowing when the car will come, and being there at the right time," says Claudia Eberlein at Loughborough University, UK.

While the new information doesn't explain how the photons were created, it certainly helps narrow the possible sources. Karimi speculates that they could be the result of a form of the dynamical Casimir effect, a quantum mechanical process where particles are produced from a moving mirror, which might be created at the surface between the water and the bubble when the bubble collapses.

Even if the photons' origin is never discovered, their quantum nature could have practical applications, says Karimi. To produce purely quantum photons for experiments, researchers need expensive lasers and tools that can cost millions of pounds. It is possible that a much cheaper set-up could be designed using a flask of water exhibiting sonoluminescence. ▮

Environment

Harmful air pollution now affects 99 per cent of people

ALMOST everyone on Earth lives in areas with harmful levels of air pollution that breach new guidelines from the World Health Organization (WHO).

The official figure is that 99 per cent of the world's population is affected, up from 90 per cent four years ago under less stringent standards.

India has nine of the world's 10 cities with the worst air pollution caused by tiny particles known as PM2.5. Ahmedabad tops the list, with Delhi in third, a new database published this week by the WHO shows. For a larger but still harmful pollutant, PM10, the top 10 list of the dirtiest places is more diverse, including settlements in Bahrain, India, Iran, Iraq, Pakistan, South Africa and Saudi Arabia.

Both pollutants are caused by a mix of fossil fuel burning in cars and power plants, but also by farming and natural sources such as desert sand. Chinese cities, which previously dominated lists of the world's most polluted urban areas, have cleaned up their air considerably. Beijing, famous for its "airpocalypse" smog events in the past, still has high annual levels of PM2.5, but is now only the 76th most polluted city globally.

In a statement, WHO chief Tedros Adhanom Ghebreyesus said: "High fossil fuel prices, energy security and the urgency of addressing the twin health challenges of air pollution and climate change underscore the pressing need to move faster towards a world that is much less dependent on fossil fuels."

"Addressing air pollution underscores the pressing need to be less dependent on fossil fuels"

Low and middle-income countries are worst affected by harmful levels of particulate matter compared with the global average. For a third pollutant – nitrogen dioxide – the economic split is less clear and affluent countries are affected too.

The WHO updated its guidelines for recommended air pollution limits for the three pollutants last September, although they aren't legally binding. ▮

Adam Vaughan

New Scientist
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Kimberley Wilson, chartered psychologist, author and a governor of the Tavistock & Portman NHS Mental Health Trust

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Analysis Coronavirus

Infections strain UK hospitals

High numbers of patients with covid-19 in wards have a serious impact on health services, even if it they are in hospital for a different reason, reports **Clare Wilson**

THE UK is currently experiencing a surge in covid-19 cases caused by the omicron variant, in common with many countries. Inevitably, the number of people in UK hospitals with the illness is also rising, and reached 2509 people admitted on 28 March – just over half the daily admissions seen at the highest peak of the pandemic in the UK in January 2021, when it reached more than 4500 per day.

> "Cases of 'incidental covid' are now about half the total number of people in hospital with the virus"

In the current wave, covid-19 is causing less severe illness than in previous waves, thanks to the lower intrinsic severity of the omicron variant and higher levels of population immunity. The number of people who need ventilation in intensive care is currently less than a tenth of the numbers seen in January 2021, the deadliest phase of the pandemic in the UK.

As a result, some people say that just tracking the total number of people with covid-19 in hospital overstates the effect of the pandemic on health services. People can go to hospital for a different reason, such as a broken leg, for example, and be found to have covid-19 only after routine testing. According to figures from NHS England, such cases of "incidental covid" are now about half the total number of people in hospital with the virus.

But dismissing all those with incidental covid underestimates the virus's impact on health services. Firstly, even if covid-19 isn't the main reason someone is admitted to hospital, it will still worsen most people's prognosis.

DAN KITWOOD/GETTY IMAGES

Ambulances at St Thomas' Hospital in London

14,268
People in English hospitals with covid-19 on 29 March

6252
People in English hospitals on 29 March being treated primarily for covid-19

11.3%
of people with covid-19 in UK hospitals in February-July 2020 became infected after admission

The coronavirus has always taken a greater toll on those who are older or medically vulnerable – and most hospital patients are likely to fit one of these categories. About two-thirds of people in hospital in the UK are over 65 and most of those who are younger are medically vulnerable just by virtue of their needing to be in hospital. Even a relatively minor operation, like a hernia repair, will leave people at higher risk from the infection.

In addition, covid-19 can manifest with less common symptoms in people who have been vaccinated, such as stomach upset or confusion in older people. So it might be someone's primary reason for admission, even it isn't recorded as such. "It's a slightly artificial distinction," says David Oliver, a physician based in Reading, UK.

Another impact is that hospitals segregate patients who test positive for covid-19, keeping them in so-called hot wards, to help reduce the spread of the virus within the hospital. People with incidental covid therefore get less attention from the doctors and nurses who are experts in their primary illness. "You get less specialist care," says Daniel Goyal, a doctor at NHS Highland.

Despite efforts at segregation, many people still catch covid-19 while in hospital. About one in 10 people in UK hospitals with the illness between February and July 2020 caught the virus during their stay.

Services stretched

It causes disruption when someone on a cold ward tests positive: everyone else has to be tested, those who are positive are moved to hot wards, and there needs to be deep cleaning. In the meantime, new people cannot be admitted to that ward, and care home residents who are positive cannot be discharged, meaning a loss of available beds.

Services are already overstretched – not least because staff absences due to covid-19 are up too. Some of those staff will have caught the virus from patients, regardless of whether they were admitted with the virus or because of it. "We know outcomes are worse if staffing is poor," says Matt Butler at Cambridge University Hospitals.

Butler hopes that in time the coronavirus will come to be seen similarly to the antibiotic-resistant bacteria MRSA or diarrhoea-causing *Clostridium difficile*. These are rarely problems for healthy people outside of hospitals and care homes, but inside such places, staff go to great lengths to stop them spreading.

With MRSA and *C. difficile*, hospital spread has been tackled by bringing in strict policies on hand washing and cleaning. For covid-19, we will also need methods of preventing airborne spread, says Butler, such as better ventilation and the use of HEPA air filters. ■

Should we worry about different variants of the coronavirus merging?

"Deltacron" variants of coronavirus pose a threat, finds **Michael Le Page**, but they aren't the worst-case scenario

THE recombinant "deltacron" variants of the coronavirus have left many people unsure about the future of the pandemic, amid fears that they could combine the delta variant's virulence with omicron's transmissibility.

Recombination, essentially the viral version of sex, occurs when a cell is infected with two related viruses, whose genetic material could mix as they replicate.

Dozens of potential recombinant SARS-CoV-2 variants have been identified in recent weeks. So, why are these emerging and how worried should we be?

Recombination can occur when a viral genome is arranged in several segments, like that of a flu virus. When new flu viruses are assembled, they may take on some segments from one variant and other segments from a second variant if it is present.

> "An entirely new variant would probably pose a greater threat than recombinants"

In contrast, the genome of the SARS-CoV-2 virus is composed of a single strand of RNA. In this case, recombinants form when the enzyme that copies the RNA releases one strand during the replication process, grabs another strand and resumes copying.

This can lead to major genetic mistakes, resulting in viruses that can't replicate. It can also generate recombinant viruses with an advantageous mix of mutations.

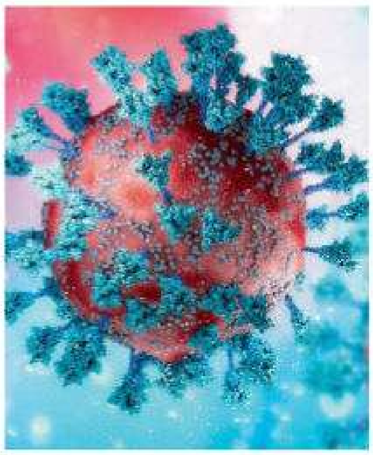
Recombination has been pivotal in the evolution of the many coronavirus strains. In humans, SARS-CoV-2 probably began recombining very early in the pandemic.

When existing variants differ by just a few mutations, it can be unclear whether a new variant with a mix of those mutations arose via recombination or if the mutations were independently acquired. Recombination is also difficult for sequencing laboratories to detect. Extra work is needed to rule out co-infections and sample contamination.

The arrival of omicron, which has more than 50 unique mutations, has made it easier to spot recombinants. It is like trying to decipher if two students have cheated: if they make the same spelling mistake on one word, it could be a coincidence, but if they misspell 10 words in the same way, someone has been copying.

The first omicron wave, caused by the BA.1 subvariant of omicron, began when the delta variant was still widespread in many countries. High case numbers mean many people would have been infected with delta and BA.1 simultaneously, creating more opportunities for recombination.

Several delta-BA.1 recombinants, known as "deltacron", have been detected, but just two have been studied sufficiently for researchers to give them names: XD and XF.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An artist's illustration of the SARS-CoV-2 virus under a microscope

XF hasn't been sequenced anywhere in the world since February and may have quickly died out. XD is still present in parts of Europe but is expected to be less transmissible than the omicron subvariant BA.2. "I'd be surprised if it managed to compete with BA.2," says Tom Peacock at Imperial College London.

BA.2 has overtaken BA.1 in many countries. Along with the relaxation of restrictions, this has triggered a second omicron wave. Many people will therefore be simultaneously infected with BA.1 and BA.2. This has created recombinants, of which seven have been named: XE, XG, XH, XJ, XK, XL and XN.

What is the risk?

So how worried should we be? With flu, recombination can create more dangerous viruses. Flu strains from other animals often kill a large proportion of the people they infect, but rarely spread from person to person.

The recombination of human and animal flu viruses could produce a strain that readily spreads between people, while remaining lethal, potentially causing a pandemic far worse than that of covid-19.

By contrast, the SARS-CoV-2 virus recombinants that have been identified so far are mixes of variants that have already spread widely in people, many of whom have some degree of covid-19 immunity. These recombinants aren't expected to differ considerably from the variants they evolved from.

A variant with novel mutations and the ability to evade past immunity would probably pose a greater threat than recombinants.

According to the UK's Scientific Advisory Group for Emergencies, the worst-case scenario is a SARS-CoV-2 variant recombining with one of the human common cold coronaviruses, or an animal coronavirus, to produce something unexpected and dangerous.

While that is possible, says Peacock, it isn't thought to be likely to happen. The more distantly related, the less likely viruses are to recombine into a functioning pathogen. ▮

VALERIA MONGELLI/BLOOMBERG VIA GETTY IMAGES

Someone with covid-19 has dialysis at a hospital in Liege, Belgium

Climate change

EU's net-zero plan has a huge flaw

The bloc's proposals for reducing emissions could lead to more deforestation

Michael Le Page

IF LAND is used to grow plants for bioenergy, it can't be used to grow food or carbon-storing forests, nor can it provide a habitat for wildlife. The European Union's proposed plan to reach net-zero carbon emissions fails to take account of this, meaning it could have unintended and undesirable consequences, such as increasing global deforestation and reducing biodiversity, according to a new analysis.

"The plans assume that converting land to energy use has no cost, which is pretty amazing given the context we are in, where we are massively clearing more land to produce more food and where climate strategies require that we reforest land," says Tim Searchinger at Princeton University.

The EU has committed itself to achieving "climate neutrality" by 2050. As an intermediate step, it is aiming to reduce emissions by 55 per cent by 2030. Last year, the European Commission unveiled a package of proposed laws, called "Fit for 55", to achieve this.

The stated aims of Fit for 55 include storing more carbon in forests and restoring biodiversity. However, the proposed measures would increase bioenergy use in the EU – whose main source of "renewable" energy is already bioenergy.

Modelling by the European Commission has estimated that the plans would require 22 million hectares of land to be devoted to energy crops, equivalent to a fifth of the EU's cropland today, says Searchinger. It also estimates that at least 10 million hectares of semi-natural grasslands will have to be converted to growing energy crops or to highly managed forests. What's more, Searchinger thinks this modelling underestimates the amount of land required.

The EU aims to store more carbon in forests, like this one in Finland

RONI REKOMAA/BLOOMBERG VIA GETTY IMAGES

The overall effect would be to greatly increase the EU's global land footprint – the area of land required to grow its food, energy crops and wood – leading to more deforestation and biodiversity loss. To meet climate goals, it is essential to reduce land footprints, says Searchinger. "If Europe increases its land footprint, we're in really bad shape."

By importing more food and wood from other countries, the EU will still be able to claim it is storing more carbon in its own forests. In fact, the EU is already burning wood from other countries and claiming it as a reduction in carbon emissions.

Searchinger and his team have calculated that by reducing biofuel usage to 2010 levels and boosting yields, Europe could free up 16.5 million hectares of land for growing carbon-storing forests and restoring biodiversity.

"In general, Fit for 55 does have lots of positive aspects," says Jan Rosenow at the non-profit Regulatory Assistance Project. But he agrees that it relies too heavily on bioenergy.

A spokesperson for the European Commission said it doesn't comment on documents that haven't yet been published, despite *New Scientist* supplying an advance copy of the analysis. ▮

Health

Holograms could help spot urinary tract infections

ANALYSING urine using holograms could lead to faster diagnoses for urinary tract infections (UTIs).

The most common urine tests have been in use for decades, but they may lack sensitivity, which can be a problem given that people with UTIs might drink water to ease their symptoms and so produce highly diluted urine.

Nicholas Durr at Johns Hopkins University in Maryland and his colleagues designed a sensitive alternative that takes a urine sample and produces a hologram – a 3D representation of an object based on detailed information from light it interacts with.

Durr and his team passed laser light through a sample of urine that had been embedded in a jelly-like substance to immobilise the floating particles it contained, then recorded the resulting pattern of light with a camera.

"We record more information than you do with a normal camera," says Durr. "That extra information allows us to know about the three-dimensional object."

Once the light has been captured, it is reconstructed into a 3D image from which it is possible to identify microscopic objects, such as cells, within the urine sample.

The system performed differently depending on the size of the objects it was measuring. For relatively large ones, such as red blood cells, it performed well enough to suggest it could have applications monitoring blood in urine. Bacteria, however, are similar in size to the camera's pixels, so it is harder to resolve particular types of bacteria within the urine and prescribe the correct antibiotic – although the system can measure overall bacterial concentrations in urine effectively (arxiv.org/abs/2203.09999).

"Even if someone has been drinking 2 litres of water, the system can still get meaningful results"

"Even if [someone] has been drinking 2 litres of water before a test, [Durr's team] can crank through very large volumes and still get meaningful results," says Jennifer Rohn at University College London. ▮

Alex Wilkins

New Scientist Video
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Technology

Slug-like slime robot could crawl through your body

Alex Wilkins

A ROBOT made of magnetic slime with a custard-like consistency can navigate narrow passages, grasp objects and fix broken circuits. It could be deployed inside the body to perform tasks such as retrieving objects swallowed by accident.

Elastic robots capable of manipulating objects and fluid-based robots that can navigate tight spaces both already exist, but versions combining both properties are less common.

To address this, Li Zhang at the Chinese University of Hong Kong and his team mixed neodymium magnet particles with borax, a common detergent, and polyvinyl alcohol, a kind of resin, to form a slime that can be controlled by an external magnetic field. They added a silicon compound that coats the magnetic particles to make them non-toxic for use in people.

The robot was tested in various scenarios, such as encapsulating a swallowed battery in a model stomach, grasping a piece of wire and squeezing through millimetre-sized gaps (*Advanced Functional Materials*, doi.org/hpbj). The slime appears to transition between tasks easily and self-heal when cut up. "You can first elongate it to a very large extent so it looks like a liquid. Then afterwards, you can roll it like an octopus' arm to carry something," says Zhang.

"They need to verify safety with future trials, but it's definitely a sound approach," says Pietro Valdastri at the University of Leeds in the UK.

ZHANG ET AL. (2022)

The slime robot engulfing a battery

Animal intelligence

Bats can remember sounds they haven't heard for years

Jake Buehler

WHEN fringe-lipped bats learn the sound of a dinner bell, they remember it for years. The bats' enduring memory is comparable to that of other animals renowned for their expansive cognitive skills, such as crows and primates.

Fringe-lipped bats (*Trachops cirrhosus*) are native to rainforests in the Central and South American tropics. They are nocturnal predators with a broad diet, snatching up insects, frogs, lizards and small mammals. The bats have a keen ear and are able to discern between the calls of poisonous and non-poisonous prey.

To see how long this ability sticks around, a team led by May Dixon at The Ohio State University in Columbus took some bats to school.

Dixon and her colleagues captured 49 fringe-lipped bats between 2010 and 2018 in Panama's Soberanía National Park. In a flight cage, the researchers trained the bats to respond to recordings of frog calls coming from a speaker by giving them pieces of fish when the noise played.

They then played a mix of frog calls and mobile phone ringtones, incrementally reducing the frog call volume and increasing the ringtone volume until the bats were trained to attack the pure ringtone sounds.

The team then taught the bats to discriminate between ringtones, providing a tasty reward for some sounds and giving them nothing when others played.

They were released into the wild, and eight of them were recaptured between 1 and 4.2 years later. When they were played their food-associated ringtones from training, all eight of the recaptured bats approached the speaker and six of them attacked it. When the researchers repeated this with 17 wild bats that hadn't received the training, only one approached the speaker (bioRxiv, doi.org/hnzn).

CHRISTIAN ZIEGLER/MINDEN PICTURES/ALAMY

A fringe-lipped bat on Barro Colorado Island, Panama

The researchers note that remembering auditory information for 4.2 years is in line with recall in highly intelligent animals: ravens have been shown to retain knowledge of past social relationships for three years, and chimpanzees can remember how to solve a food-gathering puzzle for three years.

They suggest that a long and detailed memory may be useful to fringe-lipped bats, allowing them to recognise and exploit prey animals that are rare or seasonal, so aren't encountered for extended periods.

Jesús Rafael Hernández-Montero at the ECOSUR San Cristobal research centre in Mexico is impressed by the bats' robust recall. "They get this association in a very short period of time, within 11 to 27 days of training," he says. "And then they're able to remember that 4.2 years later, so that's quite amazing."

He points out that, years later, the bats also responded to unrewarded ringtones from their training. Generalising the ringtone-food association may reflect curiosity, perhaps making them "more prone to explore new cues", he says, which would potentially improve their success at hunting.

In general, bats may be encouraged to evolve long, rich memories on account of their biology and lifestyle, says Hernández-Montero. They can live for 20 years or more, group together in complex societies and navigate complicated environments in complete darkness – all traits aided by the long-term logging of social and environmental data.

4.2

Years that bats can remember a sound they associate with food

Vladimir Pravosudov at the University of Nevada, Reno, isn't surprised by the findings. "It's cool that they found [a long memory in the bats]," he says. But he also notes that "there's lots of data suggesting that a lot of animals remember things for a long time".

One lesson emerging from these and other recent findings is that impressive cognitive traits are actually widespread across the animal tree of life, says Pravosudov. Even fish and invertebrates commonly have lengthy memories and substantial cognitive prowess.

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Archaeology

Unpublished dig notes reveal mudflow that encased the Java Man fossils

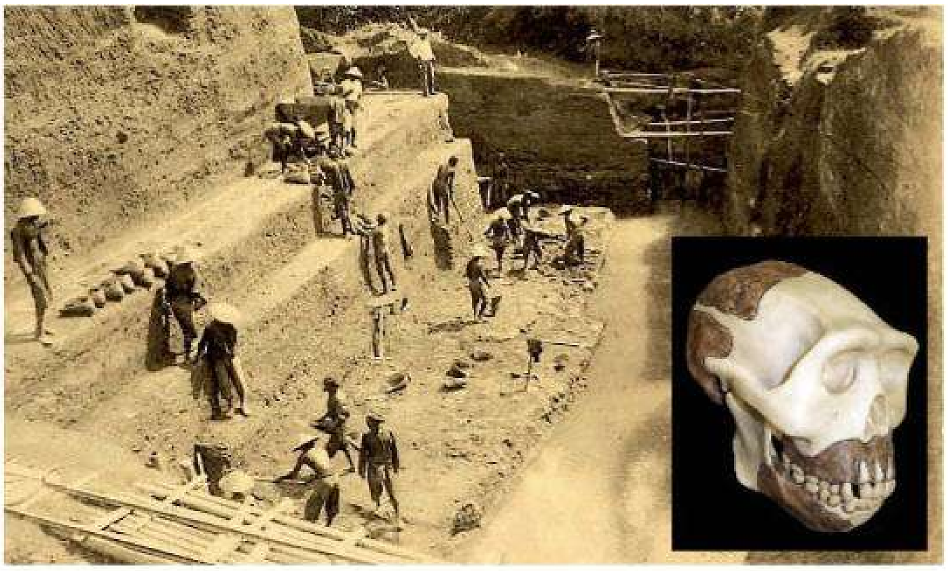
Michael Marshall

THE first big excavation of ancient human remains in Indonesia, in the 1890s, was done with great care, according to an analysis of documents from the dig.

The fossils revealed that *Homo erectus* on the Indonesian island of Java lived in a lush valley with large animals, including deer and elephants. Researchers including Paul C. H. Albers at the Naturalis Biodiversity Center in the Netherlands analysed the records, and they say the animals in the fossil bed may all have perished in a single cataclysm, probably a volcanic eruption. Later, a volcanic mudslide swept all their bones down the valley to a single site.

Homo erectus was one of the first members of the *Homo* genus, and the first known to have lived outside Africa. It was first described by Dutch researcher Eugène Dubois. Between 1891 and 1893, at a site called Trinil, Dubois and his team excavated the first recognised remains of what was known as Java Man, fossils he called *Pithecanthropus erectus* – now known as *H. erectus*.

The initial report was based on three pieces: a molar tooth, a skullcap and a femur or thigh bone. The discovery helped kick-start the study of human evolution, but many researchers have long been sceptical about the femur. "It looks too much like *Homo sapiens*," says Albers. This has led to suggestions that it is actually a modern human bone that had sunk deep into the soil.



PAUL FEARN/ALAMY; INSET: SABENA JANE BLACKBIRD/ALAMY

Trinil dig site in Indonesia, where the Java Man fossils (inset) were found in the 1890s

Albers and his colleagues have gone back over the original Trinil documents, most of which were never published. They include letters between Dubois and his site staff, letters from Dubois to the Indies government (as it was then called) and notes Dubois scribbled on unpublished photographs (bioRxiv, doi.org/hnxt).

The team concludes that he ran a careful excavation, particularly by the standards of the time. For instance, he was one of the first to divide a site into metre-by-metre squares, ensuring each discovery could be precisely localised. This approach suggests the femur really is *H. erectus*, says Albers.

In the same sediments where the *H. erectus* remains were found, Dubois and his colleagues also discovered bones of large extinct mammals, including an antlered deer called *Axis lydekkeri*, an antelope-like creature called *Duboisia santeng* and an elephant called *Stegodon trigonocephalus*. Albers says *H. erectus* probably ate at least some of them, as the species is known for hunting large animals, but there is no direct evidence of that at this site.

Indonesia offered a rich ecosystem for *H. erectus*, but it also had dangers, as revealed by the types of rock Dubois excavated at the site. Albers and his colleagues think the islands' volcanic activity is why the Trinil bone bed was so rich. Albers says an eruption may have killed hundreds of animals at once; they may have died from breathing toxic fumes. Then a lahar, a mudflow filled with rocks ejected from the volcano, swept the bones to the same site and entombed them in mud. ▮

Animals

Clever crows have a bumper count of certain brain cells

CROWS can recognise themselves in mirrors, use tools and plan for the future, all cognitive abilities more similar to those seen in non-human primates than those of most other birds. This intelligence may be related to them having an unusually high number of brain cells involved in processing information.

Felix Ströckens at the Ruhr University Bochum in Germany and his colleagues analysed the brains of common ostriches (*Struthio camelus*), brown warren chickens (*Gallus gallus domesticus*), racing homer pigeons (*Columba livia domestica*) and three members of the corvid family: carrion crows (*Corvus corone*), hooded crows (*Corvus cornix*) and rooks (*Corvus frugilegus*). The animals had all been killed for food or pest control.

The researchers were able to analyse the nuclei of the birds' brain cells using a method called isotropic fractionation. This allowed them to categorise the types of cells present in each brain and estimate how many there were of each.

The team found that corvids had the highest number of interneurons, small cells that pass on local signals and are involved in cognitive processing. These cells process information received from sensory neurons and send inputs to motor neurons. They are involved in tasks such as decision making, future planning and risk assessment (*The Journal of Comparative Neurology*, doi.org/hn9t).

> "We can assume that a higher number of neurons equals more processing power"

"If we think about the neuron as the main processing unit of the brain, we can assume that a higher number of neurons equals more processing power," says Ströckens. But it isn't enough to explain why crows have stronger cognitive abilities than most birds, he adds.

"It is an interesting and important study," says Pavel Němec at Charles University in Prague, Czech Republic. "The next frontier for research is to obtain such quantitative data for more species and test which neural feature correlates best with cognitive abilities." ▮

Jason Arunn Murugesu

Analysis Environment

Lawlessness prevails in the Amazon

Brazilian president Jair Bolsonaro has systematically undermined institutions meant to protect the rainforest, fuelling a sharp increase in deforestation, reports **Luke Taylor**

HELDER FARIA/GETTY IMAGES

Cattle ranching is a major driver of deforestation

AS A regional coordinator at Brazil's National Indian Foundation (Funai), Jussielson Gonçalves Silva was tasked with protecting Indigenous people and forests in the western state of Mato Grosso. Instead, he and two other Funai officials were leasing Indigenous reserves to cattle ranchers for kickbacks worth up to $190,000 a month, according to Brazil's federal police, who arrested the ex-navy officer on 17 March.

Gonçalves Silva is one of the many military officials who have been appointed to environmental agencies under President Jair Bolsonaro. The aim is to obstruct their work from the inside, says Suely Araújo at civil society network the Climate Observatory in São Paulo. "This case is symbolic of the growing illegality and impunity in the Amazon under Bolsonaro," she says.

Deforestation has soared since Bolsonaro took office in 2019. Another 13,235 square kilometres of the Amazon rainforest were lost in 2020-21, up 22 per cent from the previous year and the highest amount since 2006.

Conservationists largely blame the right-wing president, who has stripped back environmental protections, publicly endorsed development of the Amazon and criticised environmental institutions. "We are losing control," says Araújo, a former president of Ibama, Brazil's environment agency.

Accelerating deforestation has proved deadly for Indigenous people, many of whom have been killed in violent clashes with loggers. It has led to the loss of wildlife, and is also accelerating global warming, say ecologists. They predict that the Amazon will eventually reach a tipping point where it shifts from a lush rainforest to a more open ecosystem resembling a savannah.

13,235

Square kilometres of Amazon rainforest lost in 2020-21

A soya bean plantation in Mato Grosso, Brazil

HERBERT PICTURES/GETTY IMAGES

When that shift will occur is uncertain. But many researchers agree that Bolsonaro is bringing the date forward by weakening Brazil's environmental bodies, which has allowed organised crime groups to make mass land grabs.

Funai was founded to protect Brazil's Indigenous groups – many of whom are uncontacted – and, in turn, the country's forests, as the fate of the two are intertwined.

But Bolsonaro has obstructed these institutions legally and made them impotent by slashing their budgets and filling them with military appointments who share his pro-development agenda, says Araújo. "Institutions like Funai have almost been destroyed," she says. "They are being managed by people that are against the very proposals of the institution."

The arrest of Gonçalves Silva is the latest scandal to indicate that Funai has been tainted by politics. In January, Indigenous rights organisation Survival International obtained leaked documents suggesting that the agency discredited evidence of the existence of a previously unknown uncontacted tribe.

A Funai spokesperson said that the foundation "clarifies that it does not support any type of illicit conduct and is at the disposal of the police authorities to collaborate with the investigations. The foundation also informs that the head of regional coordination was dismissed from the position."

As Bolsonaro has weakened the institutional guardians of the rainforest, his anti-conservation rhetoric has encouraged land grabbing for cattle ranching, soya bean cultivation and illegal gold mining, says Erika Berenguer, an ecologist studying the impact of deforestation at The Sustainable Amazon Network. Guns and murders over land disputes are increasingly common as a sense of impunity in the rainforest grows.

Illegality has become so prevalent that if a new Brazilian president is elected in October, they will need to take actions akin to a peace process if they want to save the Amazon, says Adriana Ramos at Brazilian human rights and conservation group the Socio-Environmental Institute. "Imagine a region that already has a history of Indigenous leaders and environmentalists shot in land conflicts and then add a lot more guns," says Ramos.

According to conservation group WWF, over 90 per cent of deforestation of the Brazilian Amazon is illegal, but Bolsonaro is pushing to fast-track a series of bills that would make much of that lawful. Ahead of the COP26 climate summit in 2021, Brazil pledged to reach zero illegal deforestation by 2028. The promise was largely seen by experts as hollow. "This is a game that Bolsonaro is playing," says Carlos Nobre at the University of São Paulo. ▮

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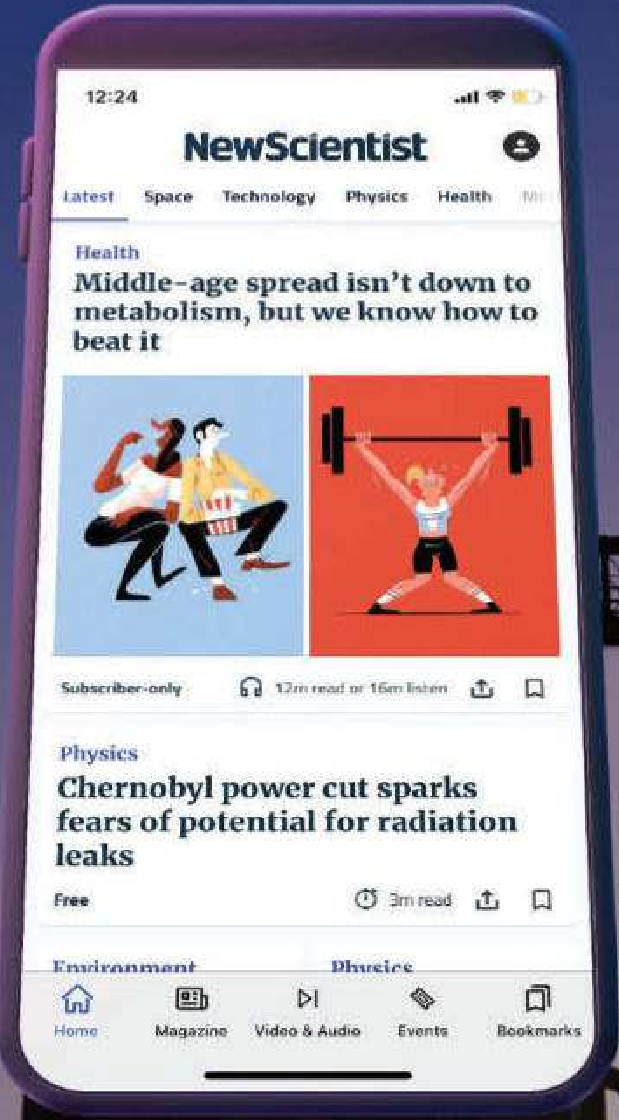

Health

Middle-age spread isn't down to metabolism, but we know how to beat it

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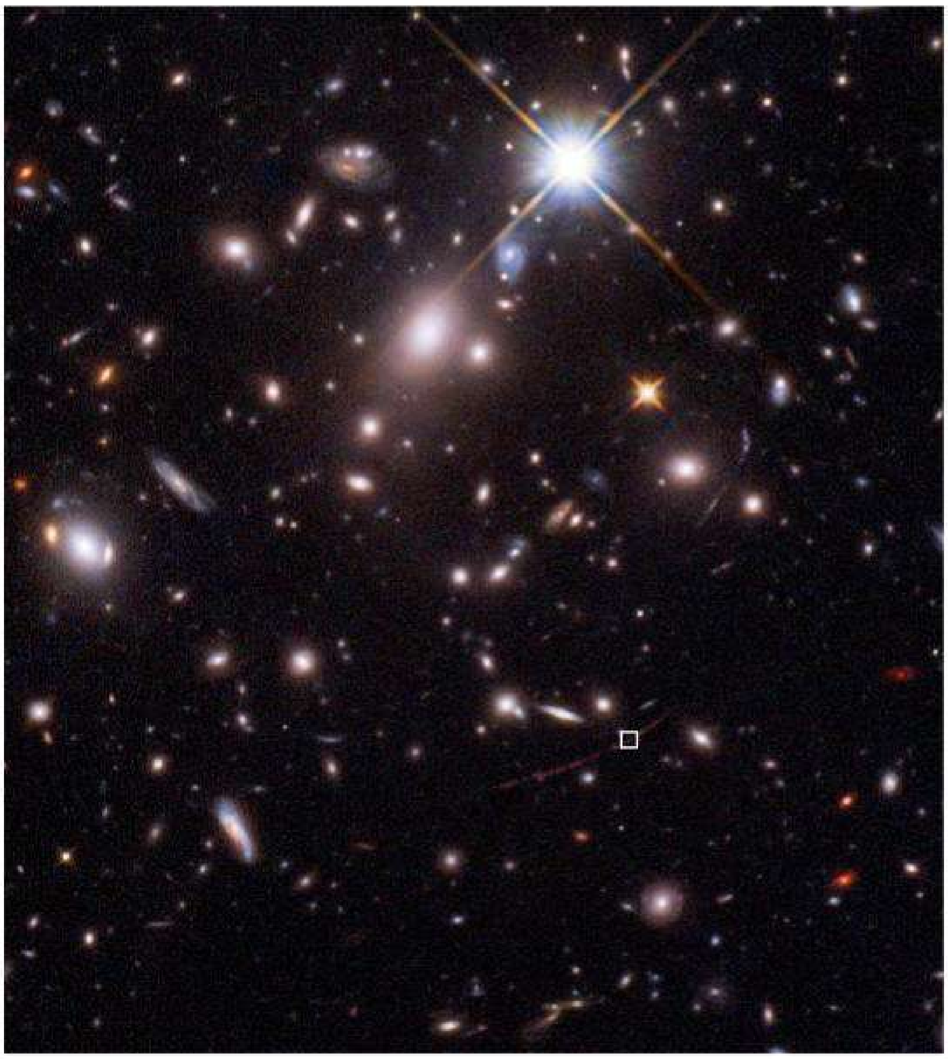
Astrophysics

Furthest star ever seen offers glimpse back in time


ESA/HUBBLE

A STAR more than 27 billion light years from Earth is the most distant individual one we have spotted. Because light takes time to travel across the universe, we are seeing the star as it existed 900 million years after the big bang, providing a window on the early universe.

Brian Welch at Johns Hopkins University in Maryland and his colleagues found the star with the Hubble Space Telescope using a process called gravitational lensing. This involves a relatively nearby galaxy or cluster of stars warping and magnifying the light from a more distant object, behaving like a lens through which we can view it.

The galaxy in which this distant star resides is nicknamed the Sunrise Arc for the shape into which gravitational lensing stretched its light, and the researchers dubbed the new star Earendel, an Anglo-Saxon word meaning "morning star" or "rising light". The star (inside the square in the picture, left) is probably between 50 and 100 times the mass of the sun.

The universe's expansion means that while the light from Earendel took about 12.8 billion years to reach us, the star is now likely to be about 27.7 billion light years away (*Nature*, doi.org/hn3v).

Further observations could reveal how stars in the early universe were different from ones formed more recently, and help solve the mystery of how supermassive black holes formed in the early universe. If it is a really massive star, "it could be the sort of thing that could form an intermediate black hole that could be the seed to a supermassive black hole", says Welch. **Leah Crane**

Evolution

Beasts' bodies grew faster than brains

AFTER the asteroid-triggered mass extinction 66 million years ago that wiped out most of the dinosaurs, small surviving mammal species underwent an evolutionary explosion. Now, it seems that the beasts evolved bigger bodies millions of years before their brain size caught up.

Ornella Bertrand at the University of Edinburgh, UK, and her colleagues looked at CT scans of mammal skulls from before and after this extinction event at the end of the Cretaceous. Some of these are new discoveries from places like the Colorado basin that show mammal evolution in the million years after the likes of Triceratops went extinct.

It was already known that the body size of mammals increased immediately after the event. Mammals at the time of the extinction were no bigger than a badger – which tend to be under a metre in length – while some were the size of a black bear 10 million years later. But Bertrand's team has discovered that the brain size of the mammals stayed about the same even as their bodies grew.

It wasn't until about 56 million years ago, during the Eocene epoch, that the palaeontologists detect sweeping changes in mammal brains (*Science*, doi.org/hn4f). "During this time," says Bertrand, "the part of the brain that increases the most is the neocortex where the integration of complex senses such as vision, hearing, motor control and memory occurs."

This increase in brain size may be partly explained by the lush forests that spread across the world in the early Eocene. Mammals underwent another evolutionary burst as they began to adapt to the thick vegetation, which made navigating, finding food and avoiding predators more complex. **Riley Black**

Health

Burning wood brings a hefty health bill

WOOD-BURNING appliances in people's homes are a major source of air pollution in the European Union and the UK, responsible for €17 billion a year in health-related costs, a study has found.

Marisa Korteland at consultancy firm CE Delft and her colleagues calculated how much air pollution is produced by heating and cooking in homes based on emissions data from Eurostat, the EU's statistical office. They used this to estimate the health cost based on a 2013 study by the World Health Organization. The estimate includes social costs of higher illness rates and earlier deaths as well as direct spending on healthcare.

PLAINPICTURE/JOZEF KUBICA

They say air pollution from fossil fuels and wood burned in homes for heating or cooking results in €27 billion of health-related costs a year in the EU and UK. Wood-based home appliances are responsible for 63 per cent (€17 billion) of the €27 billion.

The average health costs from using a wood stove for a year are €750 per household, says Korteland, compared with €210 from driving a diesel car and €30 from a gas boiler.

If countries swapped stoves and boilers for heat pumps powered by electricity from non-biomass and non-fossil fuel sources, the health-related costs from air pollution from heating could be cut to zero, the study says. **Michael Le Page**

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Really brief

BLICKWINKEL/SCHMIDBAUER/ALAMY

Fish know how to add and subtract

The zebra mbuna (pictured) and ocellate river stingray can respond to pictures of colourful shapes in a way that suggests they understand addition and subtraction. The fish learned to add or subtract "1" from a small total such as 3 in order to obtain a reward (*Scientific Reports*, doi.org/hn3p).

Warm autumns are bad for butterflies

The green-veined white butterfly forms a pupa – or chrysalis – in autumn and enters a dormant state as the weather turns cold. Now lab tests show that if the autumn is too mild, the pupa remains active and uses so much energy that a butterfly is unable to emerge in spring (*Functional Ecology*, doi.org/hn3q).

Floods after fire to occur more often

Extreme rainfall events following wildfires are set to become more common in the western US due to climate change, according to a model. The rainfall may lead to floods, because the vegetation that soaks up water has been lost during the fires (*Science Advances*, doi.org/hn9r).

Language

'People' online mostly means men

WHEN people use gender-neutral words like "people" and "humanity", they tend to be thinking of men rather than women, in reflection of sexism present in many societies, according to an analysis of billions of words published online.

The researchers behind the work warn that this sexist bias is being passed on to artificial intelligence models that have been trained on the same text.

April Bailey at New York University and her colleagues used a statistical algorithm to analyse a set of 630 billion words contained within 2.96 billion web pages, gathered in 2017. It includes informal text from discussion forums and blogs as well as text from the media, corporations and governments, mostly in English.

The researchers used an approach called word embedding to derive the intended meaning of a word from the frequency it occurs with other words. Words like "person", "people" and "humanity" were used in contexts that better match the context of words like "men", "he" and "male" than those of words like "women", "she" and "her" (*Science Advances*, doi.org/hn9q).

The study says that people may see the gender-inclusive words as more male in their conceptual meaning – a reflection of male-dominated society. This evidence of sexist bias is unsurprising, says Bailey, but it should be concerning because the same texts are used to train AI tools that will inherit this bias, including translation websites and conversation bots.

Matthew Sparkes

Human brain

SHUTTERSTOCK/CHRISTIAN HINKLE

Where you grew up affects where you navigate best

PEOPLE are better at navigating environments that are similar to those in which they grew up.

Hugo Spiers at University College London and his colleagues have previously used a mobile video game called *Sea Hero Quest* to work out that those who grew up outside cities have a better sense of direction than those who spent their childhood in these urban areas.

To do this, Spiers's team tracked how efficiently players navigated a virtual world after seeing a map.

Now, the team has analysed data from nearly 10,000 people aged 19 to 70 who played all 75 levels of the game, finding that those who grew up in cities aren't always worse at navigation. They come out on top when finding their way around grid-like structures that reflect the layout of many cities.

People who grew up in areas outside cities are better on more wiggly routes. Where people lived when playing the game had no effect (*Nature*, doi.org/hn36).

Spiers speculates that where you grow up may affect the way neurons called grid cells, part of the brain's positioning system, transmit electrical signals during a critical stage of development. These cells and their pattern of activity may then remain for life. **Carissa Wong**

Solar system

Pluto may have active ice volcanoes

PLUTO has huge ice volcanoes that may still be active. An analysis of data from NASA's New Horizons spacecraft has revealed that at least 180,000 square kilometres of Pluto's surface is made of ice that seeped out from underground via cryovolcanism relatively recently.

This area, around two mountains called Wright Mons and Piccard Mons, is made up of undulating hummocks of ice. "There's not really anything anywhere else in the solar system that looks like this," says Kelsi Singer at the Southwest Research Institute in Colorado.

Singer's team examined images, data and maps of the area and found that it was probably created via effusive cryovolcanism. This is when liquid or soft ice seeps out from underground to gradually create mountains. Wright Mons and Piccard Mons appear to be cryovolcanoes as large as the biggest active volcanoes on Earth, but there is no evidence of explosive eruptions (*Nature Communications*, doi.org/hn4c).

The lack of impact craters from asteroids hints that the ice isn't that old. "It probably formed within the last couple hundred million years, but we're not sure if it's still ongoing," says Singer. **LC**

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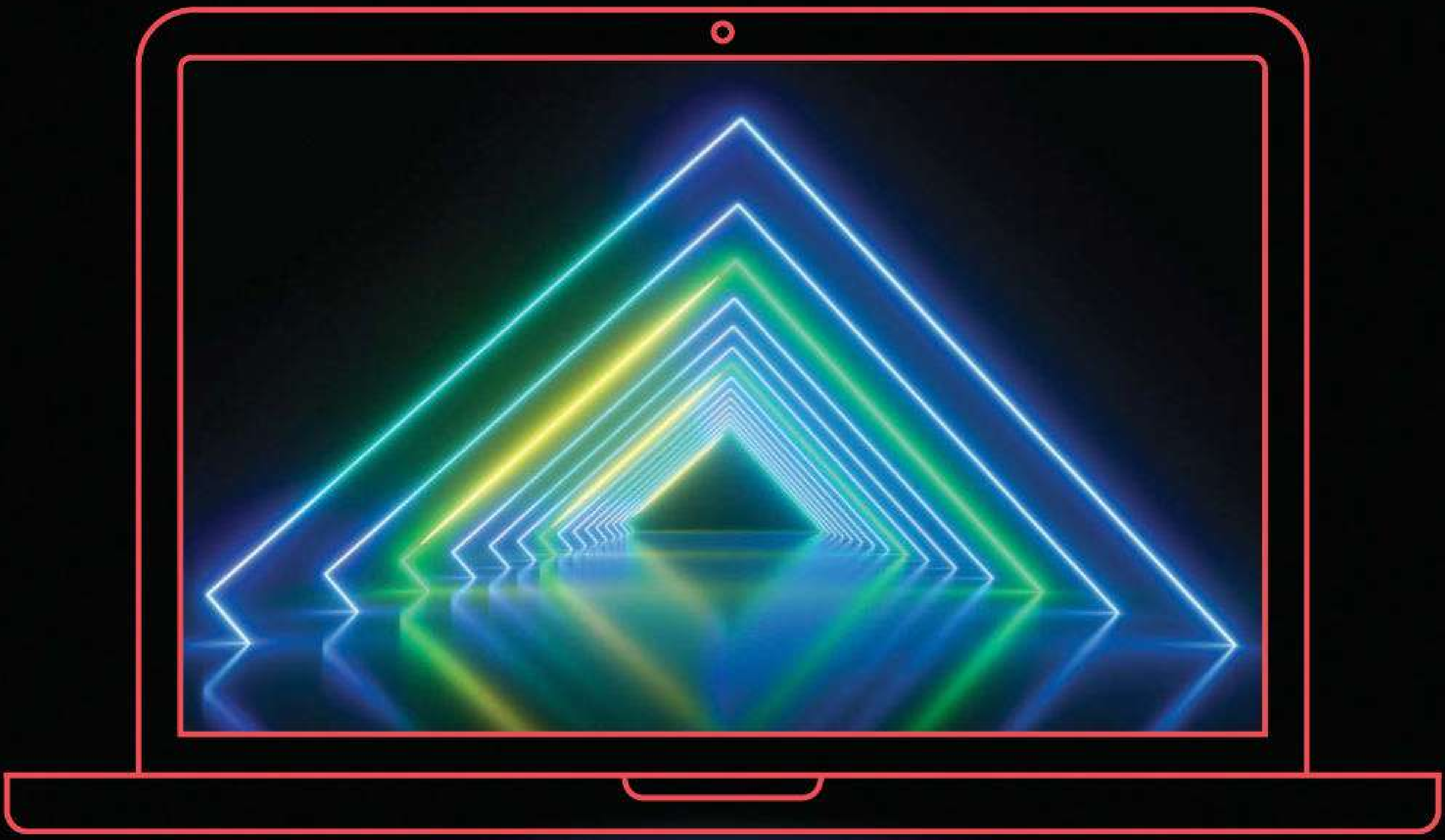

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Views

The columnist
Focus on plant loss more, says **Beronda L. Montgomery** p27

Aperture
The strange arteries criss-crossing Earth's surface p28

Letters
Dealing with coughs and sneezes isn't always easy p30

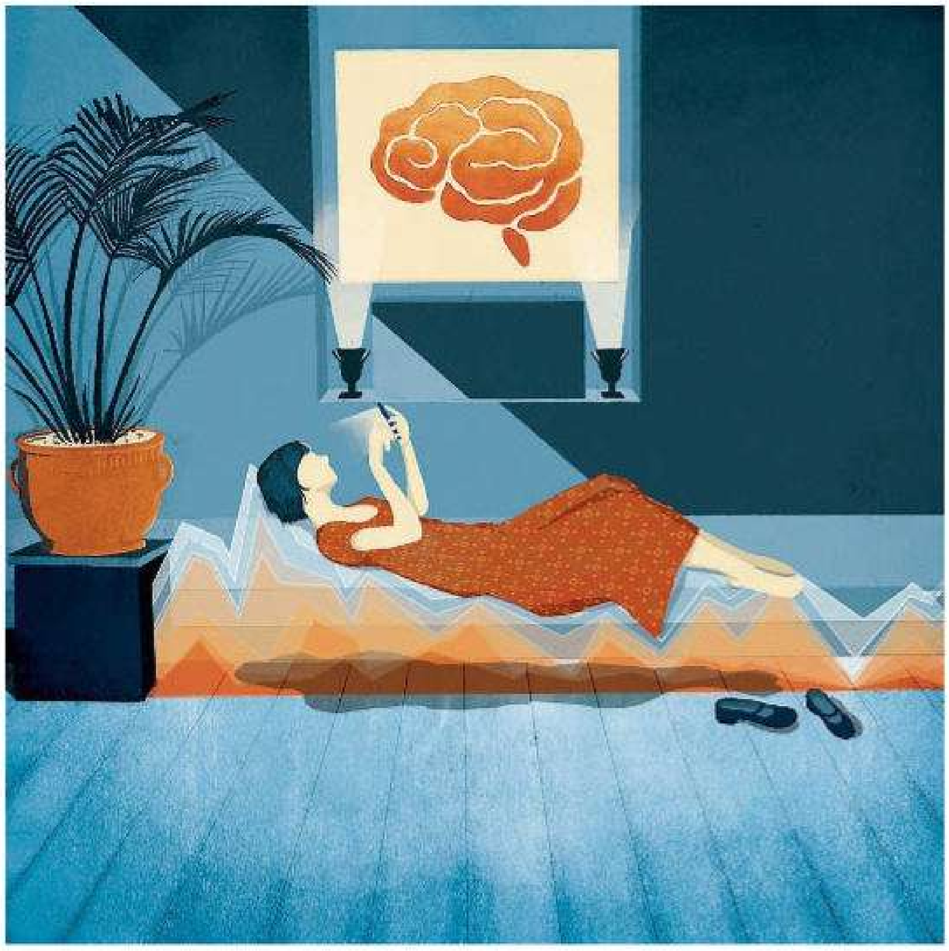
Culture
An intriguing look at the role of luck in our lives p32

Culture columnist
Sally Adee explores the power of memes in sci-fi p34

Comment

Smart therapy?

Difficulties getting face-to-face psychiatric therapy have led to the rise of tech alternatives, but how helpful are they, asks **Eleanor Morgan**



SIMONE ROTELLA

ACROSS all forms of psychiatric therapy, there is a focus on developing a relationship between patient and therapist. This is known as the therapeutic alliance, a crucial factor in the success of sessions. But such therapy can be expensive, hard to access and have long waiting times, so many people don't get to experience this kind of relationship.

Tech companies have stepped in to fill the gap, and people wanting fast support can now use an app rather than having to wait feeling frustrated or demoralised. In many ways this is good, but there are reasons to be cautious about the boom in easy access therapy.

Therapy apps often use computerised cognitive behavioural therapy models, mindfulness and journalling to help people manage low-mood and anxiety. The popular self-therapy app Bloom offers guided exercises to help users examine their thoughts and behaviour, featuring a library of pre-recorded video clips, with titles such as "Learning to love yourself". Happify claims that "your emotional well-being can be measured", scores it for you and provides games and tasks, like cognitive behavioural therapy-informed thought exercises, to help you improve your mood.

Such discreet, low-cost interventions may help increase self-awareness and offer a sense of control, but a recent meta-analysis of mobile app mental health interventions – based on data from nearly 50,000 users – didn't find convincing evidence that apps improved low mood or reduced anxiety or suicidal thoughts (*PLoS Digital Health*, doi.org/gpgmn3).

There can also be a placebo effect: a 2018 study compared the guided meditation app Headspace – one of the most popular on the market, with 2 million subscribers in 2020 – against a "sham" app that focused on guided breathing without a mindfulness aspect. Participants reported improved outcomes like critical thinking (being able to analyse uncomfortable thought patterns, say) with both versions.

A therapy app may seem a proactive step, and capturing someone's thought patterns is technically possible via clinical questionnaires like the GAD-7, which apps may create their own versions of. The results can then be used to gauge improvements. However, self-reporting bias means we only ever have a minor understanding of what is going on. We can't explore the deeper meaning of someone's emotional problems with standardised questionnaires, least of all without another human present.

Then there is the issue of data. If we are sharing vulnerable information with an app, it would be good to know how that information will be handled. A 2019 study found that nearly half of such apps didn't have a privacy policy. The study references the meditation app Happify, stating that it "requested 18 permissions, including access to users' text messages and contacts list". On reviewing Happify's current privacy policy, there is no mention of text messages, but other information still gets collected.

Bloom states that it may partner with third parties to share information in order to provide or improve its services. This may seem like inoffensive language when you want to get started on trying not to feel bad. Then you see Bloom advertising on huge billboards with statements like: "To all 8k users who felt tired. We're here to wake you up."

Tech companies analysing our private thoughts and plastering them up on the streets feels like a wake-up call. The therapy sector needs a radical overhaul for many reasons, and the tech solutions offered in this unregulated field may help in some way, for some people. But at what cost? ▮

Need a listening ear? Visit bit.ly/SuicideHelplines for hotlines and websites around the world.

Eleanor Morgan is a journalist and trainee psychotherapist @eleanormorgan

Welcome to our Signal Boost project – a page for charitable organisations to get their message out to a global audience, free of charge. Today, a message from the **Royal Entomological Society**

CHRYSOLINA BANKSII BY ÁNGEL PLATA SÁNCHEZ

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- Invest in our workforce and infrastructure.

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Want to join our global community of insect scientists? Everyone is welcome. Find out more at www.royensoc.co.uk and www.insectweek.co.uk

My botanical life

Trees under fire

We don't focus enough on the loss of plants in times of crisis, but our ability to recover is deeply affected by the plants sharing our communities, writes **Beronda L. Montgomery**

Beronda L. Montgomery is a writer, researcher and biochemist who studies how plants detect and respond to their local light environment. She is the author of *Lessons from Plants*. You can follow her on Twitter @BerondaM

Beronda's week

What I'm reading

South to America: A journey below the Mason-Dixon to understand the soul of a nation *by Imani Perry.*

What I'm watching

I am revisiting High on the Hog: How African American cuisine transformed America.

What I'm working on

I am revising my next paper on lessons we can learn from nature about equity in community.

SPRING is springing in Michigan, where I live, and I am scheduling frequent walks to welcome the vibrant wildflowers that will soon emerge – beautiful white trilliums, marsh marigolds and bright red wild columbine.

After two years of mostly working at home due to the pandemic, I have been limited to observing the plants growing in my own house, flower and vegetable gardens and the neighbourhood. I have also been soaking up other plants virtually, through social media. Monstera Mondays, Houseplant Hour, Black Botanists Week, Plantstagram and many other plant communities have flourished online during the pandemic. While some initially thought they might need to grow their own vegetables, others have drawn comfort and peace from caring for plants or simply observing them.

As I recently began to travel again, the practising plant biologist in me has been fascinated to encounter plants that have also endured, and were likewise endeavouring to emerge from challenging times.

I have seen devastated plant communities, destroyed alongside the humans living in the same spaces. In late 2021, I encountered many of the hundreds of trees in Iowa whose entire top canopy had been severed by a derecho in 2020. This long-lasting storm ravaged parts of the Midwest, causing a tragic loss of human life and massive physical damage to buildings and natural spaces. I saw evergreen trees with completely flat tops, as their distinctive points had been obliterated. The abruptly shortened trunks of deciduous oak and maple trees were more stark evidence of the damage caused by the storm.

Many of the millions of trees damaged by the Midwest derecho, one of the most costly storms in US history, were removed due to the threat their skeletons posed. Other badly injured trees are now on a path to recovery. For trees, an initial rest and recovery phase is followed by a period of actively forging new paths of branch and leaf growth.

Plants and trees in general are quite resilient – a number of the trees I encountered in Iowa had already initiated the development of callus tissue that results in a massive scab forming over the wound of a broken branch or severed trunk. This is evidence of healthy trees labouring to move forwards from trauma.

> "I have seen devastated plant communities, destroyed alongside the humans living in the same spaces"

A recent trip to California brought me into contact with vastly scorched tracts of forests damaged by massive blazes in the past couple of years. Groves of giant sequoia trees in the state have been decimated by fires, and Redwood Mountain Grove in Kings Canyon National Park was largely destroyed.

Giant sequoias are adapted to fire. They can withstand – and indeed depend on – low-intensity fire for reproduction. But climate change and human interventions are changing the frequency and intensity of forest fires that ultimately lead to massive sequoia losses. When killed by fire, these large trees become huge skeletons that are hard to ignore. Such remnants are a key reminder of the impact of disasters on our communities that can be forgotten when we are understandably focused on the devastation affecting human lives.

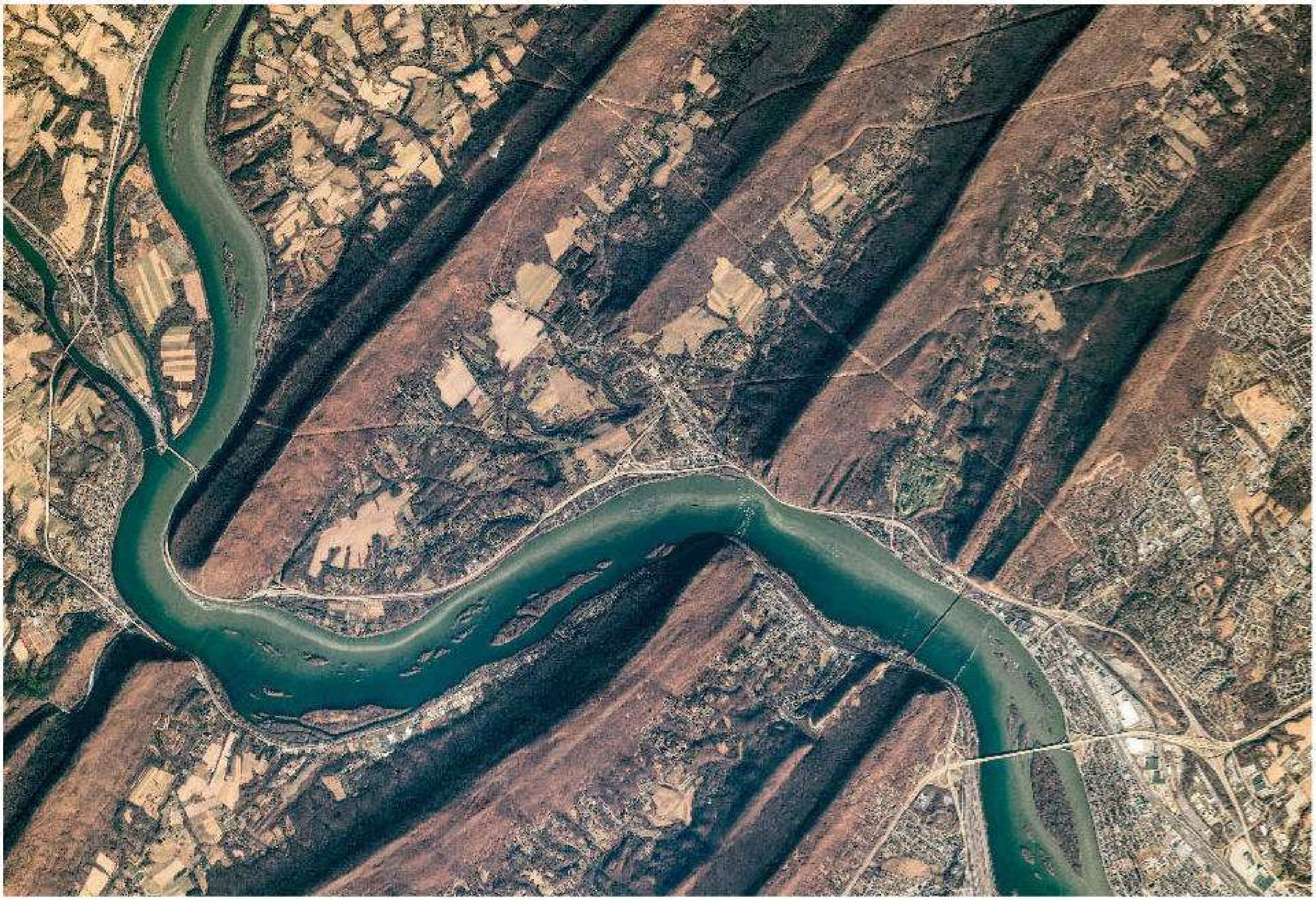
War, too, is both a humanitarian and environmental crisis. Watching Russia's attack on Ukraine unfold, and mourning the lives senselessly lost, I also notice the damage to pine and hornbeam birch trees, as well as to vineyard and orchard landscapes, in images from sites of conflict.

When forest fires, derechos or hurricanes occur, it is our natural response to concentrate on the loss of human life and the economic damage. We sometimes make note of the impact of such events on flora and fauna, most notably the economic fallout due to effects on crop plants.

But while we may not focus on the loss of vegetation in times of disaster, our capacity to recover is deeply affected by the equivalent abilities of our plant neighbours, including the contributions these organisms make to the production of oxygen and to food supply. In the 2020 growing season, more than 12,000 square kilometres of farmland were destroyed by fires in California, affecting many vegetable, fruit and nut crops.

The plants living right alongside us often escape our notice. Human plant awareness can be limited outside our regular cultural engagement with them at times of celebration and grief. Yet these beings are our living neighbours. Finding a way forward through crisis is made easier if we can see all of the lives that are negatively affected, including those plants sharing our communities. We have to see them in their fullness – both how they add beauty to our existence and are essential to it – to work to save them, just as we seek to save ourselves. ▮

Up next week:
Chanda Prescod-Weinstein



NASA

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New Scientist video
Watch a clip from *River* and many other videos at **youtube.com/newscientist**

Earth's arteries

DRAMATIC, powerful and entrancing, these images give a bird's-eye view of one of humanity's most valuable resources. They are taken from *River*, a new nature documentary directed by Jennifer Peedom. The movie includes drone footage and draws on modern filming techniques, such as the use of satellites, to capture the scale and intricacy of rivers in 39 countries across six continents.

Though rivers make up only about 1 per cent of the world's surface freshwater, they are critical sources of drinking water and food for countless people. Rivers are also biodiverse ecosystems that play vital roles in distributing nutrients and draining surface water. Yet they are increasingly at risk from pollution, damming and biodiversity loss, making the need to protect them all the more urgent.

The images show (clockwise, from top left): North America's Susquehanna river as it cuts through agricultural land in Pennsylvania, taken from the International Space Station; glacial outflows in Iceland captured by photographer Chris Burkard; an abandoned fishing boat sitting in the mudflats of the Colorado river delta, an area under threat from drought and climate change; and, finally, a double meander of the Colorado river in Canyonlands National Park, Utah.

River is screening in selected cinemas and available to watch on demand at river.film.

Gege Li

Editor's pick

Dealing with coughs and sneezes isn't always easy

19 March, p 27

From Ian Davies,
Port Talbot, West Glamorgan, UK

Jonathan Goodman says we should ensure that coughing and sneezing in public is treated as a social crime. I disagree.

He compares such behaviours with exposure to human waste. The chances of the latter are slim, while it is easily possible to cough and sneeze without having an infectious disease. Speaking as someone who has endured many summers with hay fever, I know the misery of sneezing, sniffing, having a runny nose and feeling unwell. The last thing I want is to be reviled in public by the self-appointed health police.

By all means, the public should do all it can on personal hygiene, but don't start persecuting people with long-standing health conditions.

From Eric Kvaalen,
Les Essarts-le-Roi, France

I agree about the need to cover our mouths and noses when we cough or sneeze. But more than that, the policy should be that when you are sick, you don't go to the workplace.

I was in a company where we had an allowance of sick days per year, but only if you went and sat in a waiting room to see a doctor and got a note from them. People would either do that and spread virus in the waiting room, or just forget it and go to work.

Some people might abuse the new approach and take days off when they aren't actually sick, but I think that is a price worth paying for less disease overall.

Good to correct Victorian distortions of biology

12 March, p 27

From Jonathan Wallace,
Newcastle upon Tyne, UK

As Lucy Cooke argues, there is little doubt that Victorian patriarchal attitudes influenced the interpretations that 19th-century biologists placed on animal behaviour and led them to some incorrect conclusions. The amazing diversity of life is reflected in a similar diversity of sexual behaviours in the animal kingdom, and the advances in our understanding of this, many made by female scientists, are welcome.

I was disappointed, however, by Cooke's assertion that a "feminist perspective is urgently needed" in the study of animal sexual behaviour. Research should never be driven by an ideological perspective, as it risks reaching conclusions that are just as wrong as those made by the Victorians.

Try to land a plane and a harsh reality may dawn

26 March, p 15

From Peter Slessenger,
Reading, Berkshire, UK

Many non-pilots may believe they can land a plane after watching a YouTube video, but they might think twice if faced with reality.

Certainly, if this applied to an airliner, even if you managed to touch it down, you would then be driving a 120-tonne racing car with unfamiliar handling as it bounced along – and yes, they do bounce.

As a former glider pilot, I reckon I could land one if necessary, provided I had a professional pilot talking me through everything and was in perfect conditions, but the plane might not be all in one piece afterwards.

Perhaps Stonehenge is to do with the moon's phases

12 March, p 21

From John Kitchen, Kettering,
Northamptonshire, UK

The idea that 30 stones in a circle at Stonehenge represent the days of a month is a bit odd. The sun doesn't circle the site at all, let alone once a month. The people who built Stonehenge were farmers, not factory workers. They didn't care what day it was, they were more interested in seasons.

What would be interesting is if Stonehenge could track the phases of the moon as well as the sun. Some farmers sow their fields based on the new moon or full moon, around the vernal equinox.

So many places where we could up the tree count

Letters, 12 March

From William Croydon,
Sandown, Isle of Wight, UK

Victoria Hiley suggests turning car parks into woodlands. We could also go back to planting standard trees into hedges, particularly alongside roads, and in streets within towns. In addition to sequestering carbon, this would help wildlife and provide shade to reduce summer temperatures.

I am reminded of a yesteryear description of the UK's New Forest by someone who called it "the most beautiful arms factory that I've worked in". This is a reference to the fact that many of the woodlands were planted after the Napoleonic wars to provide trees to build future naval ships.

We must embrace solutions that, while perhaps not perfect, provide multiple benefits to society with minimum disruption.

Let's talk about the puffin-rabbit relationship

19 March, p 43

From Blaise Bullimore,
Haverfordwest, Pembrokeshire, UK

In the article on the fate of rabbits, it is mentioned that puffins use rabbit burrows for nests.

The naturalist Ronald Lockley addressed this in a paper in *British Birds* in 1937 looking at puffins on Skokholm, an island to which your story refers. He concluded puffins will and do use rabbit burrows, but their bills and feet equip them well for digging their own. He also found that rabbits cause damage to puffin burrows. So puffins will do fine without rabbits.

If something is beyond testing, then is it science?

12 March, p 55

From Brian Horton, West
Launceston, Tasmania, Australia

I appreciated Tom Gauld's cartoon depicting a physics professor stressed out by the bizarre theories in parts of the field that no one actually understands.

I have noticed that some of your physics articles present ideas that aren't currently testable, and in many cases may never be tested. Since a requirement of scientific study is that we can test our predictions, I often wonder if physics is a real science.

There are other solutions to some nuclear waste

5 March, p 19

From Peter Roby,
Watford, Hertfordshire, UK

You report that the latest estimate for the cost of an underground repository for UK nuclear waste has risen to as much as £53 billion, which includes storing legacy uranium and plutonium that were deemed an "asset in the past".

I wonder if many people are aware that a new generation of nuclear power companies, such as the UK's Moltex and others, can run their newly designed, low-pressure, molten salt-cooled reactors on nuclear waste and the aforementioned stockpiles.

These kinds of technologies that can deal with nuclear waste and make energy from some of it will be operating within a decade, and perhaps much sooner if we have the will to back it. ▮

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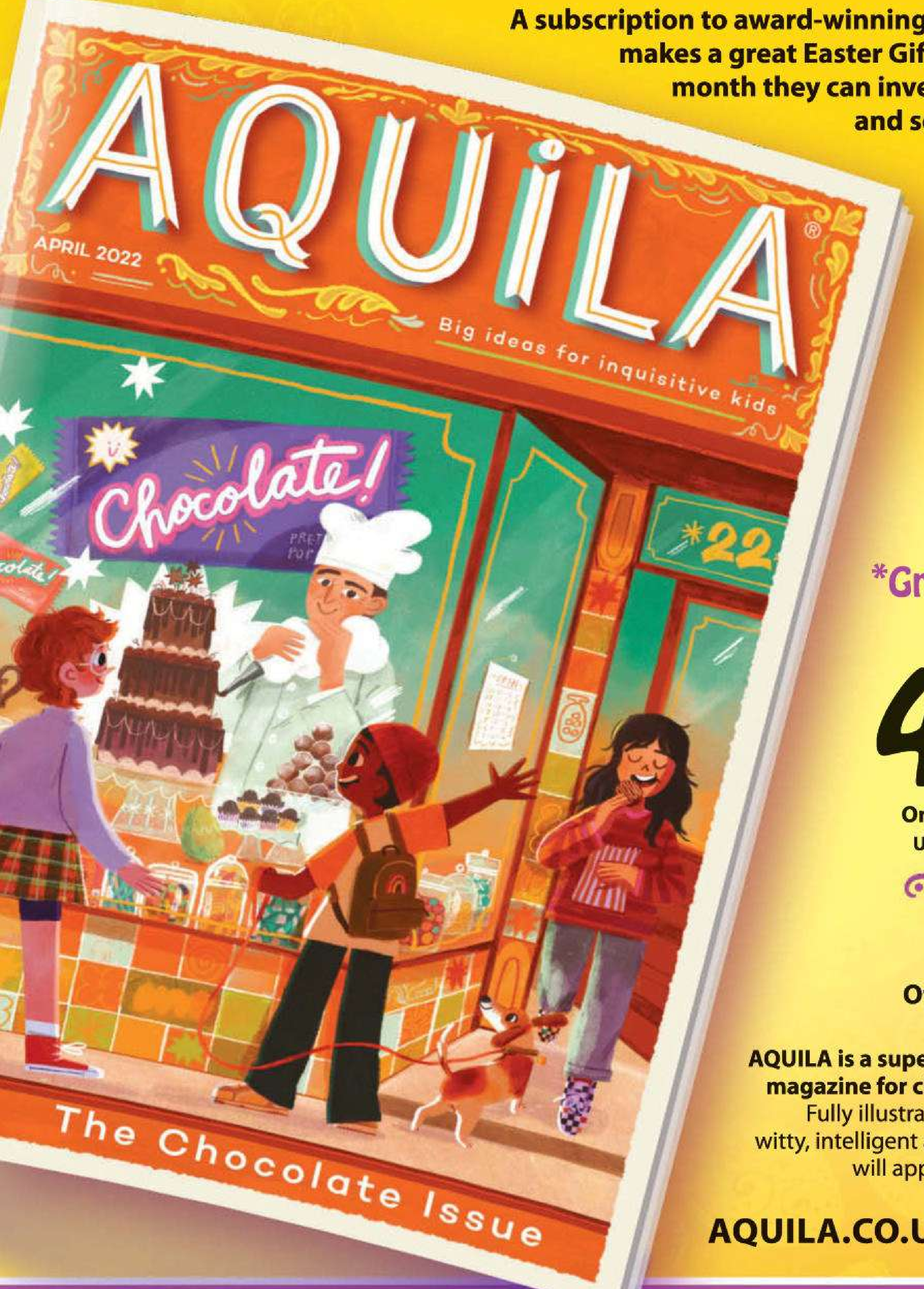

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I should be so lucky

The experiences of a semi-professional gambler make an intriguing starting point to explore our belief in luck, says **Simon Ings**

Book

Luck: A personal account of fortune, chance and risk in thirteen investigations
David Flusfeder
4th Estate

RUSSIAN novelist Fyodor Dostoevsky was a gambling addict. He believed that if he could only maintain his composure, the various strategies and systems he dreamed up to beat the roulette wheel would one day pay off. He was kidding himself. No strategy can defeat pure chance.

David Flusfeder is a semi-professional poker player, who knows all about the thrill of the gamble. In *Luck,* he bypasses the scientific harsh truth about randomness and probability and instead has written a book about the human side of luck, which he defines as "the operations of chance taken personally".

His eccentric, insightful meditations focus on fortune's favourites and its gulls throughout history. We hear the stories of the Marquis de Dangeau, 18th-century Versailles's wiliest card shark, right up to the experience of four-time lottery winner Joan Ginther, also known as"the luckiest woman on Earth".

In an effort to stop his project sprawling, each of the essays here is largely self-contained. They have to be, because Flusfeder decided to put the hand of fate to good use by presenting them in an order determined by an online randomiser.

Dostoevsky's experience is perhaps the most compelling. Even after he managed to rid himself of his addiction, the novelist retained the conviction "that in games of chance, if one has perfect control of one's will, so that the subtlety of one's intelligence and one's power of calculation are preserved, one cannot fail to overcome the brutality of blind chance and to win."

Flusfeder reckons Dostoevsky was born in the wrong place at the right time; he should have been playing poker with French settlers in New Orleans. The card game invented there in 1829 really does reward composure and nerve, as well as luck.

Not that poker is an altogether rational pursuit. If it were, then Flusfeder wouldn't be wearing green underpants to every important game. Superstition abounds on the poker circuit, as it does wherever people wield little or no control over their lives. Professional tennis is one example, writes Flusfeder. "There is so much time to think, and doubt, and lose the learned rhythms of technique, and to be afraid", that the sport is awash with lucky tics, habits and absurd pre-match routines, he points out.

> **"Superstition is the inevitable result of our capacity for taking mental shortcuts, and thinking on our feet"**

Superstition, Flusfeder argues, isn't some primitive hangover from our distant past. It is the inevitable result of our capacity for taking mental shortcuts, which makes us capable of thinking on our feet, and without which we wouldn't be able to function at all. If we had to constantly re-evaluate what was going on around us, we would quickly get left behind.

Instead, our brains make reasonable assumptions and update them if necessary. Along the way, we develop habits, and the impression that we live in a deterministic world in which what happened yesterday is a reliable guide for our actions today.

This works well enough in day-to-day life, but, writes Flusfeder, the extension of this very human way of thinking to economics often fails when it turns out that past results are an imperfect guide to future performance.

On this, statistician David Spiegelhalter, who studies the public perception of risk, puts it bluntly. Probability doesn't exist outside the mind, he says: "It is not an objective aspect of the world. It's a way to operationalise a belief." At best, he says, it provides us with a map to help us navigate outcomes that are immeasurable and ultimately unknowable.

Given our weaknesses in the face of randomness, how should we proceed? According to Flusfeder, rather than cowering from the unknown and avoiding all randomness, we should pick our battles carefully, seizing good fortune when it arises, while swerving unnecessary risks. It is an imperfect guide to life, but it is a start at least.

Virtue may be an even better option, says Flusfeder. A life lived with honesty and integrity will at least be consistent, whether we are suffering adversity or enjoying good fortune. As the Renaissance poet Petrarch put it: "Many times whom fortune has made bond, virtue has made free." ▮

Simon Ings is a writer based in London

Superstition abounds on the poker circuit, where players wield little control

DEEPOL BY PLAINPICTURE/PLATTFORM

Secrets of the Arctic

A portrait of three intrepid scientists brings the reality of glacial melting into sharp focus, finds **Davide Abbatescianni**

Film

Into the Ice

Lars Henrik Ostenfeld

CPH:DOX Film Festival

CPH:DOX 2022

Leading glaciologist Alun Hubbard descends into a seemingly bottomless crevasse

A MAJESTIC aerial shot of the Arctic landscape opens Lars Henrik Ostenfeld's epic documentary *Into the Ice*. Then his narration hits us with the hard truth: "The Greenland inland ice harbours a secret. You can see our future in it." As if to illustrate what that future might look like, the camera then pans to deep rivers of meltwater.

The message of Ostenfeld's film is familiar, yet what sets it apart is its focus on the fieldwork of three of the world's leading glaciologists: Alun Hubbard, Dorthe Dahl-Jensen and Jason Box. Ostenfeld travels with them, on three separate trips, to the Arctic as they monitor how fast the Greenland ice sheet is melting.

Ostenfeld provides intimate portraits of the researchers, highlighting their distinct personalities and the motivations behind their work. Box is a family man who, when he isn't playing with his daughter, is happiest digging the snow while listening to ABBA's hit *Chiquitita*. Hubbard, the most adventurous of the three, embraces the idea of living every day as "a complete surprise". His perilous descent into the depths of a seemingly bottomless crevasse is a case in point.

Dahl-Jensen, as Box describes her, is "about science with a capital S" and is dedicated to drilling ice cores as a window into the past. "When you walk through ice, you walk on climate history," she says. She points to a darker ice layer, which dates from the last glacial period, while a more distant, lighter part is from an interglacial period.

During his time with the researchers, Ostenfeld becomes fully immersed in their work and their mission. His presence is well balanced and respectful, and his feelings of concern, fear and admiration emerge beautifully through his intimate voice-over commentary.

In this way, Ostenfeld achieves his aim of creating a strong empathic bond with the audience. This allows him to deliver a more serious message about the importance of studying changes in the ice as they are happening, no matter how perilous an undertaking it may be.

Throughout, we learn how the study of ice and its history are essential to uncovering the scope and consequences of climate change, and the importance of collecting and analysing data that will help us update our predictions of global sea level rise.

The initial light-hearted tone and good humour of the scientists gradually give way to a more serious feel as the realities of life and work in the Arctic become clear. We see the scientists face a lashing storm that forces them to hide in their tents for two days. And we feel their fear and excitement as they take on the elements to gather data.

The dangers of fieldwork become only too apparent as Box learns of the death of his mentor, climate scientist Konrad Steffen, who fell into an ice crevasse elsewhere in Greenland, on a separate research trip.

Towards the end of the film, Box and Hubbard head back into the deep crevasse to resume their work, only to discover an uncomfortable truth: the meltwater under the ice has progressed to a level never seen before. The glaciers are melting at a faster pace than we thought and our predictions of sea level rise are probably too cautious.

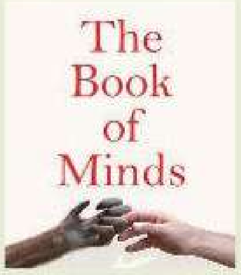
Accompanied by striking imagery and an engaging instrumental score, *Into the Ice* is a powerful documentary and one of the unmissable titles of this year's festival season. It doesn't try to soften the blow or to end on a hopeful note. Instead, it is a touching wake-up call, rich in sincerity and brutal home truths. ▮

Davide Abbatescianni is a writer based in Cork, Ireland

Don't miss

Watch

The Naked Mole-rat: Animal Superhero by evolutionary ecologist Chris Faulkes will explain how this rodent altered our view of human health and ageing. This online talk by London's Linnean Society is on 13 April at 12.30 BST.



Read

The Book of Minds by Philip Ball argues that we must look beyond our own brains and delve into the minds of other creatures if we want to truly understand ourselves and comprehend the possibility of alien or machine intelligence.

Watch

Outer Range stars Josh Brolin as a rancher in the Wyoming wilderness whose grip on reality is called into question when a mysterious black void opens up in his western pasture. It will stream on Amazon Prime from 15 April.

TOP: CHRIS FAULKES AND LORNA FAULKES; BOTTOM: AMAZON STUDIOS

The sci-fi column

When memes go bad

A growing micro-genre of sci-fi literature is exposing the power of infectious ideas and the horrors they can inflict on our perception of reality, says **Sally Adee**

Sally Adee is a technology and science writer based in London. Follow her on Twitter @sally_adee

Books

And Then I Woke Up
Malcolm Devlin
Tordotcom (from 12 April)

There is No Antimemetics Division
Sam Hughes (qntm)
Self-published

The City & the City
China Miéville
Picador

Sally also recommends…

Book

Sea of Tranquility
Emily St John Mandel
Picador (from 28 April)
From the fine mind that produced Station Eleven *and* The Glass Hotel *comes another treat: a century-spanning, genre-crossing, time-travel book about the nature of reality, set in a near-future of pandemics and parallel worlds.*

MIRCEA MOIRA/SHUTTERSTOCK

"THE quality wasn't very good, but it was good enough for a debate," says Spence, the narrator of Malcolm Devlin's short but powerful horror novella *And Then I Woke Up*. He is describing the viral video that kicked off the zombie apocalypse. "Some people said the men were kissing, some insisted one was biting the neck of the other," Spence recalls. "He was eating him, they said. Eating him!"

Without giving too much away, Spence is recounting these events from the rehabilitation facility where infected people are slowly reintegrated into society. But if you think I just spoiled the plot, think again. This zombie apocalypse is nothing like what you have been taught to expect by previous books and movies. Devlin has written a horror story where the "zombies" are memes.

Memes are, of course, ideas that lend themselves to jumping from one brain to another. Like that trick where someone tells you not to think about an elephant, once the image has made its way into your mind, you can't stop the chain of events that unfolds.

Richard Dawkins coined the term meme for the phenomenon in 1976, back when it was a relatively unproblematic aspect of how units of culture are transmitted through society. But in our hyper-networked world, memetic spread has become uncontrolled and uncontrollable, and there is something a little unsettling about it. From the QAnon conspiracy theory to the cheezburger cat, there is no telling what will show up in your feed or who produced it. Whether you consent or not, it will nestle between the folds of your brain and start to lay its eggs.

> "Memes can set our expectations, distorting and warping them with someone else's narrative"

This sinister process is well established in neuroscience: where our expectations lead, our perceptions of reality follow. Memes can set those expectations, distorting and warping them with someone else's narrative.

> **In our hyper-networked world, memetic spread has become uncontrolled**

Sometimes, these are harmless, like the dress that seems to be both blue and white or the audio version, yanny/laurel. Other times, they are more sinister, like the kissing men who may or may not be cannibals, or a conspiracy theory that a pizza restaurant had paedophiles in its basement. Memes can even distort what is right in front of your face.

While the events of Devlin's book are horrifically plausible, in *There is No Antimemetics Division* by Sam Hughes (also known by the pseudonym qntm), perceptual expectations are managed by some of the creepiest supernatural beings imaginable. As they lurk unseen by almost everyone, they wreak havoc on an unsuspecting public, who make sense of things by inventing narratives to explain the horrors around them. An entity that creeps around collecting fingers, for example, is explained away as an unusually high rate of kitchen and carpentry accidents.

Devlin and Hughes aren't the first to explore the power that infectious memes wield over our reality. In *The City & the City*, China Miéville showed readers two overlapping metropolises in which citizens are trained from birth to "unsee" any evidence of the other city and its residents.

Authors are increasingly waking to the hypnotic power of memes, a topic that is becoming more relevant by the year. These three books are a great introduction to this growing micro-genre of science fiction. I recommend all three of them to the skies. You might end up with a mild case of existential horror, but at least, unlike the stories' protagonists, you will know what to expect. ▮

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Tasked with shaping and delivering PML's Digital Science Strategy you will provide lab-wide strategic leadership to facilitate digital transformation across all science areas, mentoring colleagues and enabling PML to fully embrace a Big Data future and capitalise on digital tools and techniques such as AI and Machine Learning.

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Essential requirements:

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- Demonstrable understanding of the tools and infrastructure required for carrying out digital-centric research (coding; data formatting and manipulation)
- Experience in securing external funding to support research activities, training and capital infrastructure investment
- Ability to demonstrate the interoperability between the different datasets which form the PML data ecosystem and data ecosystems held elsewhere.

To discuss the role in more detail please contact Steve Widdicombe, swi@pml.ac.uk

Senior Scientists (x4) £40,486 - £46,410 pa

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- Proficiency in working with large datasets or synthesis within your research, using a range of coding, data formatting and manipulation techniques
- Ability to lead research collaboratively across specialisms, together with project and financial management experience
- A track record of securing research funding
- Experience of conducting social or natural science within an interdisciplinary setting.

To discuss the role in more detail please contact Steve Widdicombe, swi@pml.ac.uk

Data Systems Architect £32,527 - £38,486 pa

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To discuss the role in more detail please contact Tim Smyth, tjsm@pml.ac.uk

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Extreme encryption

A clever form of cryptography allows us to see data without ever looking at it. Could this dispel the privacy fears that hobble big data? **Edd Gent** investigates

LIKE any doctor, Jacques Fellay wants to give his patients the best care possible. But his instrument of choice is no scalpel or stethoscope, it is far more powerful than that. Hidden inside each of us are genetic markers that can tell doctors like Fellay which individuals are susceptible to diseases such as AIDS, hepatitis and more. If he can learn to read these clues, then Fellay would have advance warning of who requires early treatment.

This could be life-saving. The trouble is, teasing out the relationships between genetic markers and diseases requires an awful lot of data, more than any one hospital has on its own. You might think hospitals could pool their information, but it isn't so simple. Genetic data contains all sorts of sensitive details about people that could lead to embarrassment, discrimination or worse. Ethical worries of this sort are a serious roadblock for Fellay, who is based at Lausanne University Hospital in Switzerland. "We have the technology, we have the ideas," he says. "But putting together a large enough data set is more often than not the limiting factor."

Fellay's concerns are a microcosm of one of the world's biggest technological problems. The inability to safely share data hampers progress in all kinds of other spheres too, from detecting financial crime to responding to disasters and governing nations effectively. Now, a new kind of encryption is making it possible to wring the juice out of data without anyone ever actually seeing it. This could help end big data's big privacy problem – and Fellay's patients could be some of the first to benefit.

It was more than 15 years ago that we first heard that "data is the new oil", a phrase coined by the British mathematician and marketing expert Clive Humby. Today, we are used to the idea that personal data is valuable. Companies like Meta, which owns Facebook, and Google's owner Alphabet grew into multibillion-dollar behemoths by collecting information about us and using it to sell targeted advertising.

Data could do good for all of us too. Fellay's work is one example of how medical data might be used to make us healthier. Plus, Meta shares anonymised user data with aid organisations to help plan responses to floods and wildfires, in a project called Disaster Maps. And in the US, around 1400 colleges analyse academic records to spot students who are likely to drop out and provide them with extra support. These are just a few examples out of many – data is a currency that helps make the modern world go around.

> "Even insignificant nuggets of information can be used to identify people in the data"

Getting such insights often means publishing or sharing the data. That way, more people can look at it and conduct analyses, potentially drawing out unforeseen conclusions. Those who collect the data often don't have the skills or advanced AI tools to make the best use of it, either, so it pays to share it with firms or organisations that do. Even if no outside analysis is happening, the data has to be kept somewhere, which often means on a cloud storage server, owned by an external company.

You can't share raw data unthinkingly. It will typically contain sensitive personal details, anything from names and addresses to voting records and medical information. There is an obligation to keep this information private, not just because it is the right thing to do, but because of stringent privacy laws, such as the European Union's General Data Protection Regulation (GDPR). Breaches can see big fines.

Over the past few decades, we have come up with ways of trying to preserve people's privacy while sharing data. The traditional approach is to remove information that could identify someone or make these details less precise, says privacy expert Yves-Alexandre de Montjoye at Imperial College London. You might replace dates of birth with an age bracket, for example. But that is no longer enough. "It was OK in the 90s, but it doesn't really work any more," says de Montjoye. There is an enormous amount of information available about people online, so even seemingly insignificant nuggets can be cross-referenced with public information to identify individuals.

One significant case of reidentification from 2021 involves apparently anonymised data sold to a data broker by the dating app Grindr, which is used by gay people among others. A media outlet called The Pillar obtained it and correlated the location pings of a particular mobile phone represented in the data with the known movements of a high-ranking US priest, showing that the phone popped up regularly near his home and at the locations of multiple meetings he had attended. The implication was that this priest had used Grindr, and a scandal ensued ›

CHRIS MALBON

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because Catholic priests are required to abstain from sexual relationships and the church considers homosexual activity a sin.

A more sophisticated way of maintaining people's privacy has emerged recently, called differential privacy. In this approach, the manager of a database never shares the whole thing. Instead, they allow people to ask questions about the statistical properties of the data – for example, "what proportion of people have cancer?" – and provide answers. Yet if enough clever questions are asked, this can still lead to private details being triangulated. So the database manager also uses statistical techniques to inject errors into the answers, for example recording the wrong cancer status for some people when totting up totals. Done carefully, this doesn't affect the statistical validity of the data, but it does make it much harder to identify individuals. The US Census Bureau adopted this method when the time came to release statistics based on its 2020 census.

Trust no one

Still, differential privacy has its limits. It only provides statistical patterns and can't flag up specific records – for instance to highlight someone at risk of disease, as Fellay would like to do. And while the idea is "beautiful", says de Montjoye, getting it to work in practice is hard.

There is a completely different and more extreme solution, however, one with origins going back 40 years. What if you could encrypt and share data in such a way that others could analyse it and perform calculations on it, but never actually see it? It would be a bit like placing a precious gemstone in a glovebox, the chambers in labs used for handling hazardous material. You could invite people to put their arms into the gloves and handle the gem. But they wouldn't have free access and could never steal anything.

This was the thought that occurred to Ronald Rivest, Len Adleman and Michael Dertouzos at the Massachusetts Institute of Technology in 1978. They devised a theoretical way of making the equivalent of a secure glovebox to protect data. It rested on a mathematical idea called a homomorphism, which refers to the ability to map data from one form to another without changing its underlying structure. Much of this hinges on using algebra to represent the same numbers in different ways.

"The promise is massive. It is almost hard to put a bound on what we can do if we have this technology"

Imagine you want to share a database with an AI analytics company, but it contains private information. The AI firm won't give you the algorithm it uses to analyse data because it is commercially sensitive. So, to get around this, you homomorphically encrypt the data and send it to the company. It has no key to decrypt the data. But the firm can analyse the data and get a result, which itself is encrypted. Although the firm has no idea what it means, it can send it back to you. Crucially, you can now simply decrypt the result and it will make total sense.

"The promise is massive," says Tom Rondeau at the US Defense Advanced Research Projects Agency (DARPA), which is one of many organisations investigating the technology. "It's almost hard to put a bound to what we can do if we have this kind of technology."

In the 30 years since the method was proposed, researchers devised homomorphic encryption schemes that allowed them to carry out a restricted set of operations, for instance only additions or multiplications. Yet fully homomorphic encryption, or FHE, which would let you run any program on the encrypted data, remained elusive. "FHE was what we thought of as being the holy grail in those days," says Marten van Dijk at CWI, the national research institute for mathematics and computer science in the Netherlands. "It was kind of unimaginable."

One approach to homomorphic encryption at the time involved an idea called lattice cryptography. This encrypts ordinary numbers by mapping them onto a grid with many more dimensions than the standard two. It worked – but only up to a point. Each computation ended up adding randomness to the data. As a result, doing anything more than a simple computation led to so much randomness building up that the answer became unreadable.

In 2009, Craig Gentry, then a PhD student at Stanford University in California, made a breakthrough. His brilliant solution was to periodically remove this randomness by decrypting the data under a secondary covering of encryption. If that sounds paradoxical, imagine that glovebox with the gem inside. Gentry's scheme was like putting one glovebox inside another, so that the first one could be opened while still encased in a layer of security. This provided a workable FHE scheme for the first time.

Workable, but still slow: computations on the FHE-encrypted data could take millions of times longer than identical ones on raw data. Gentry went on to work at IBM, and over the next decade, he and others toiled to make the

We generate vast amounts of data about ourselves as we go about our lives online

SHUTTERSTOCK/WONDERLUSTPICSTRAVEL

process quicker by improving the underlying mathematics. But lately the focus has shifted, says Michael Osborne at IBM Research in Zurich, Switzerland. There is a growing realisation that massive speed enhancements can be achieved by optimising the way cryptography is applied for specific uses. "We're getting orders of magnitudes improvements," says Osborne.

IBM now has a suite of FHE tools that can run AI and other analyses on encrypted data. Its researchers have shown they can detect fraudulent transactions in encrypted credit card data using an artificial neural network that can crunch 4000 records per second. They also demonstrated that they could use the same kind of analysis to scour the encrypted CT scans of more than 1500 people's lungs to detect signs of covid-19 infection.

Also in the works are real-world, proof-of-concept projects with a variety of customers. In 2020, IBM revealed the results of a pilot study conducted with the Brazilian bank Banco Bradesco. Privacy concerns and regulations often prevent banks from sharing sensitive data either internally or externally. But in the study, IBM showed it could use machine learning to analyse encrypted financial transactions from the bank's customers to predict if they were likely to take out a loan. The system was able to make predictions for more than 16,500 customers in 10 seconds and it performed just as accurately as the same analysis performed on unencrypted data.

CREDIT: ERIC AUDRAS/ONOKY - PHOTONONSTOP/ALAMY

Sharing medical data, like these MRI scans, can risk violating patient privacy

Suspicious activity

Other companies are keen on this extreme form of encryption too. Computer scientist Shafi Goldwasser, a co-founder of privacy technology start-up Duality, says the firm is achieving significantly faster speeds by helping customers better structure their data and tailoring tools to their problems. Duality's encryption tech has already been integrated into the software systems that technology giant Oracle uses to detect financial crimes, where it is assisting banks in sharing data to detect suspicious activity.

Still, for most applications, FHE processing remains at least 100,000 times slower compared with unencrypted data, says Rondeau. This is why, in 2020, DARPA launched a programme called Data Protection in Virtual Environments to create specialised chips designed to run FHE. Lattice-encrypted data comes in much larger chunks than normal chips are used to dealing with. So several research teams involved in the project, including one led by Duality, are investigating ways to alter circuits to efficiently process, store and move this kind of data. The goal is to analyse any FHE-encrypted data just 10 times slower than usual, says Rondeau, who is managing the programme.

Even if it were lightning fast, FHE wouldn't be flawless. Van Dijk says it doesn't work well with certain kinds of program, such as those that contain branching logic made up of "if this, do that" operations. Meanwhile, information security researcher Martin Albrecht at Royal Holloway, University of London, points out that the justification for FHE is based on the need to share data so it can be analysed. But a lot of routine data analysis isn't that complicated – doing it yourself might sometimes be simpler than getting to grips with FHE.

For his part, de Montjoye is a proponent of privacy engineering: not relying on one technology to protect people's data, but combining several approaches in a defensive package. FHE is a great addition to that toolbox, he reckons, but not a standalone winner.

This is exactly the approach that Fellay and his colleagues have taken to smooth the sharing of medical data. Fellay worked with computer scientists at the Swiss Federal Institute of Technology in Lausanne who created a scheme combining FHE with another privacy-preserving tactic called secure multiparty computation (SMC). This sees the different organisations join up chunks of their data in such a way that none of the private details from any organisation can be retrieved.

In a paper published in October 2021, the team used a combination of FHE and SMC to securely pool data from multiple sources and use it to predict the efficacy of cancer treatments or identify specific variations in people's genomes that predict the progression of HIV infection. The trial was so successful that the team has now deployed the technology to allow Switzerland's five university hospitals to share patient data, both for medical research and to help doctors personalise treatments. "We're implementing it in real life," says Fellay, "making the data of the Swiss hospitals shareable to answer any research question as long as the data exists."

If data is the new oil, then it seems the world's thirst for it isn't letting up. FHE could be akin to a new mining technology, one that will open up some of the most valuable but currently inaccessible deposits. Its slow speed may be a stumbling block. But, as Goldwasser says, comparing the technology with completely unencrypted processing makes no sense. "If you believe that security is not a plus, but it's a must," she says, "then in some sense there is no overhead." ▮

Edd Gent is a journalist based in Bangalore, India

RUPERT GRUBER

Lost footprints of our ancestors

Fossilised tracks can provide a window on the everyday fears and joys of ancient people – if you know how to read them. **Colin Barras** reports

A YOUNG woman is struggling across a muddy plain with a 3-year-old child on her left hip. She puts the youngster down to catch her breath. But she is too afraid to pause for long. The pair are alone, an easy target for the sabre-toothed cats that may lurk nearby. She picks up the child again and hurries on, vanishing into the distance. For a time, all is quiet. Then a giant ground sloth plods across the path she took. The animal catches the woman's scent and is instantly on guard, rearing up and turning to scan the landscape for human hunters.

What was it like to live in the Stone Age? There must have been moments of joy, fear, love, pain and perhaps even wonder for the people who inhabited Earth tens of thousands of years ago. But emotions don't fossilise, so we are shut out of those moments, separated by a vast chasm of time. We can find all the bones and tools we like, but they won't tell us about the experience of life for our ancient ancestors.

Then again, a new window on their everyday existence may be cracking open. As people went about their lives, they left untold numbers of footprints behind. These recorded their behaviour in a unique way, capturing everything from nervous shuffles to determined sprints. What's more, the tracks have an order to them, meaning events can be read like a narrative. That story of the woman, the child and the giant sloth is a vivid example we have found written in ancient tracks – but it certainly isn't the only one. An explosion in discoveries of ancient footprints is revealing a new portrait of the past, from the division of labour between the sexes to the behaviour of long-extinct animals.

Archaeologists have known for decades that footprints can fossilise. In 1976, for instance, a research team discovered 3.7-million-year-old footprints at Laetoli, an archaeological site in Tanzania. They were instantly important for showing that an early species of hominin called *Australopithecus afarensis* – of which the best-known example is a fossil named Lucy – walked on two legs rather than on all fours, as some had argued.

At the time, footprints were seen as a useful source of evidence for basic anatomical facts about a species, plus where and when it lived. Even so, the discovery at Laetoli didn't trigger a rush to find more ancient prints. "It was thought they were really rare," says Matthew Bennett at Bournemouth University, UK.

The fact that few researchers looked for more was unfortunate, says Bennett, because ancient footprints are actually common. They were produced in enormous quantities, perhaps a million per person each year, so even though only a tiny proportion will have ended up as fossils, that is still a lot. "My bones have one opportunity to make it into the fossil record," says Kevin Hatala at Chatham University in Pittsburgh, Pennsylvania. "But all the steps I take every day – I have an enormous opportunity to make it into the fossil record that way."

One way footprints can end up being preserved is if a person walks over a blanket of ash from a volcanic eruption, which then hardens like quick-drying concrete on exposure to moisture. This is how the Laetoli footprints fossilised, but it is a rare process. It is far more common for footprints in wet sand or mud to get quickly covered with dry sand and dust blown in by a storm. These get buried and fossilise, and then geological processes can push them back up to the surface.

Although ancient footprints were a low archaeological priority for decades, things are finally changing. The past 20 years have seen an eruption in the number of ancient footprint sites. They can be found in almost every corner of the world – in Africa, Europe, the Arabian peninsula, Australia and the Americas.

Following the trail

It is also becoming clear that footprints can paint a surprisingly intimate picture of the past. For instance, it is well-established from lab experiments that the size and shape of someone's foot can predict their body size fairly accurately. And since body size generally differs between the sexes, you can potentially estimate the sex of the individual who made a set of footprints. Foot length is also known to be roughly 15 per cent of someone's height, while the distance between prints made by the same foot allows you to estimate someone's walking or running speed. "Footprints are reflective of how tall you are, your age, your sex, potentially even your weight," says archaeologist Ashleigh Wiseman at the University of Cambridge.

All these factors came together during a 2020 study of more than 400 footprints at a site in Tanzania called Engare Sero. Hatala and his colleagues used deductions from the ›

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prints to reconstruct a scene from roughly 12,000 years ago. They found the tracks belonged to at least 17 people from our own species, *Homo sapiens*, making this the largest collection of ancient human prints ever found in Africa. The researchers concluded that the group was probably comprised of 14 women, two men and a youngster. All members of the group were walking at the same speed – a leisurely 1.2 to 1.5 metres per second – which suggests they were travelling together.

Armed with this kind of evidence, we can begin to make educated guesses at what these people were up to. In modern hunter-gatherer communities, groups of women often work together to forage for food. This could be what was going on in the ancient group. If so, it tells us something about the division of labour between the sexes at the tail end of the Stone Age. "I don't know how you would potentially observe that sort of social dynamic using any other line of archaeological evidence," says Hatala.

> **"The trails typically meander across the landscape, like a family on a Sunday stroll"**

Some of the most thrilling footprints to emerge so far were found at a site called White Sands National Park in New Mexico. This isolated area is surrounded by a missile range and has spectacular dunes and salt flats that make it popular with film-makers. It contains a huge playa, or dried-up lake, where we have long known there are fossilised footprints from ancient animals. In 2017, David Bustos, who works with the National Park Service at White Sands, discovered human footprints. Shortly afterwards, Bennett travelled there to search for more prints. He has been investigating intensely ever since.

"Most of the trackways at White Sands involve a couple of adults and a gaggle of children," says Bennett. The trails typically meander across the landscape, the sort of thing you would expect from a family on a Sunday afternoon stroll. But one set that Bennett, Bustos and their colleagues came across was different: tracks of a single person striding out in a straight line. These would prove to be the prints that told the story of the young woman, the child and the ground sloth. But Bennett and Bustos didn't know that when they first set out to follow the trail.

Soon, they realised there were actually two sets of tracks: one heading roughly north for at least 1.5 kilometres; the other, less than

Cave of the sacred bison

If you want to read information from footprints, it pays to turn to the experts. People from some Indigenous communities depend on their ability to track animals during hunts. This fact hasn't been lost on scientists.

For more than a century, archaeologists have puzzled over 17,000-year-old human footprints found in the Tuc d'Audoubert cave in southern France. Many of the prints were made using the heels only, leading to the suggestion that they may be evidence of some ritual, linked to a nearby sculpture of two lifelike bison.

In 2013, a European team invited three Ju/'Hoansi trackers from Namibia to take a look. "They told me it was a challenge," says Dam Debe, a Ju/'Hoansi tracker and a colleague of the trio. The footprints were far older than those the trackers normally encounter.

They did, however, arrive at a new interpretation of the events that took place in the cave millennia ago. The prints are those of a teenager and a man in his 30s who were busily collecting clay from a small pit in the cave floor to make the bison sculpture.

Why did they walk on their heels? Because, said the trackers, a knowledgeable person can recognise a member of their community from their full footprint. Walking on the heels is awkward, but it is an effective way for someone to conceal their identity – which might have been important to the sculptors if the artwork had ritual significance.

"I feel that the approach the trackers employ is similar to the methods used by Western scientists," says Megan Biesele at the Kalahari Peoples Fund in Austin, Texas, who witnessed the trackers at work in France.

Clay bison sculptures in Tuc d'Audoubert cave in the south of France

GRANGER/SHUTTERSTOCK

NPS/USGS/BOURNEMOUTH UNIVERSITY

Many human footprints have been discovered at White Sands National Park in New Mexico (below). Sometimes excavations are required to follow the tracks (top)

a metre away, taking the same route south. They deduced that the northerly prints came first because they are crossed and partially distorted by footprints left by two large, now-extinct animals, a mammoth and a giant ground sloth. The human southerly prints, by contrast, sit on top of the animal footmarks.

Statistical analysis showed no clear difference in the size and shape of the northerly and southerly prints, so they were probably left by the same person. The fact that this individual didn't deviate from their course on either journey is significant, says Bennett. "It says: I'm on a mission."

Who was this person? Bennett and his team established that the prints were left by a slender individual, probably a young woman. It is also clear she was in a hurry. Running the numbers, her pace was clocked at 1.7 metres per second, which is faster than the average modern walking speed. It is particularly brisk given that the going was tough – the footprints record plenty of evidence that the woman slipped as she hurried on her way. "There was urgency of movement," says Bennett.

Special delivery

What was her mission? On the northerly journey, some of the prints from her left foot show a rotational slip in the soft mud, giving them a banana shape. Bennett suspects she was unbalanced on her left because she was carrying a burden on her hip. At a few points along the northerly trackway, we catch a glimpse of that burden: there are a handful of footprints belonging to a child of no more than 3 years old. It appears the woman was carrying the child and occasionally put them down, perhaps to rest or to give the child a break.

We don't know the woman's destination. The northerly prints vanish into the White Sands missile range, beyond the reach of investigation. But there are no indications that the woman was still carrying the child in the southerly prints. One interpretation of the events is that she was delivering the child to someone. Whether she succeeded or not, she returned alone.

Stories like this mean a lot to Kim Charlie and Bonnie Leno. They are both members of the Pueblo of Acoma near Albuquerque in New Mexico, one of several groups of Pueblo people who feel a spiritual connection to White Sands. Charlie is a committee member of the regional Tribal Historic Preservation Office, while Leno, her sister, is a designated tribal monitor, meaning she collaborates with scientists to share her traditional knowledge of the area. Both have visited White Sands to see the archaeologists at work. "It's just fascinating," says Charlie. "There are no words to describe how you feel when you're actually there."

The fact that Leno discovered some footprints herself during the visit – a human print near one left by a giant sloth – only added to the excitement. With her knowledge of the region, Leno already has a strong sense of where people once lived and where they travelled. "You could say we see things beyond the archaeologists' view," she says. "That could be because these were our ancestors." There has also been at least one case where a partnership between researchers and people with traditional knowledge has helped interpret the meaning of footprints (see "Cave of the sacred bison", left).

Bennett stresses there is always a risk of pushing footprint analysis too far in pursuit of a captivating story – what he calls "palaeo-poetry". It is tempting to argue that the woman hurried because she was wary of roaming sabre-toothed cats, but we will never know

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A 3.7-million-year-old print preserved in ash in Laetoli, Tanzania

JAVIER TRUEBA/MSF/SCIENCE PHOTO LIBRARY

for sure. Still, footprints do pitch us closer than ever to the emotions of ancient people.

The evidence does strongly suggest that fear hung in the air that day, and maybe in more than one species. The giant ground sloth acted oddly when it crossed the woman's northerly tracks. Its own footprints show that it reared up on its hind legs and shuffled around in a circle. The obvious conclusion, says Bennett, is that it had picked up the woman's scent and, anxious about the possible presence of hunters, was scanning the landscape. This might have been typical sloth behaviour, says Bennett. There are plenty of other ground sloth tracks elsewhere at White Sands. They show that the beasts usually trundled in a roughly straight line, he says. But some trails are different. “Suddenly, the prints do an about-face and head off at a different angle,” he says. “And when we look at that point of inflection, we'll find a human footprint.”

Landscape of fear

One collection of prints at White Sands, described by Bennett, Bustos and their colleagues in a 2018 study, even captures a sloth hunt, with humans literally walking in the animal's footprints before attacking. But if sloths did fear humans, the same doesn't go for some other animals. Mammoths and even camel trails don't deviate when crossing human trackways, telling us they had a more relaxed attitude to early Americans. “It's really breathing life into these animals,” says Bennett.

> **“Children were splashing in the muddy puddles left in the sloth footprints”**

The footprints at White Sands aren't all about the gruelling struggle to survive though. In unpublished work, Bennett and his team have discovered some that seem to record a moment of pure joy. The researchers found a chaotic mess of footprints belonging to a gang of children, the oldest no more than 6 years old. The tiny prints are focused around the large impressions left by yet another ground sloth. The logical conclusion, says Bennett, is that the children were splashing in the muddy puddles left in the deep sloth footprints. “Kids have always liked to jump in puddles,” says Bennett. “These are stories that can connect people with the past.”

Beautiful tales aside, footprints still have the capacity to throw up surprises about the grand sweep of human history. It turns out White Sands might end up at the centre of one much-debated question: when did humans first begin to populate north America?

For decades, it was assumed the first settlers were connected to a style of stone tool first found at another site in New Mexico called Clovis. Today, the consensus is that the Clovis culture – which is about 13,000 years old – isn't the earliest evidence of human activity in the Americas. Instead, the accepted archaeological and genetic evidence suggests people began living there about 15,000 years ago. But there is a nagging suspicion this isn't the final answer. A number of archaeologists have found evidence that they claim shows humans were in north America thousands of years earlier, at the peak of the last glacial period. However, the evidence is contested.

White Sands is throwing up new clues. The whole area is composed of layers of rock of different ages that are exposed in different places. One day, Bennett and his colleagues found a set of human tracks padding across the dirt and vanishing beneath a small hill. This suggested the tracks were older than the hill – particularly ancient, then. Crucially, the researchers could test their hunch, because the dirt around the prints contained grass seed that could be radiocarbon-dated. In September 2021, they reported the results: the 61 footprints were between 21,000 and 23,000 years old. It is the most incontrovertible evidence yet that the peopling of America took place much earlier than we thought.

“White Sands is a fantastic discovery,” says Ciprian Ardelean at the Autonomous University of Zacatecas in Mexico, who has also found archaeological evidence suggesting that humans were in the Americas much earlier than 20,000 years ago. He doesn't think ancient footprints should overshadow traditional artefact-based archaeology. But he has previously suggested that White Sands might come to be seen as pivotal in the story of the earliest Americans.

This kind of legacy doesn't interest Bennett. But he does hope the work at White Sands will encourage other archaeologists to go looking for footprints elsewhere in the region. Because the most remarkable part of this story is that White Sands might prove to be unremarkable in the grand scheme of things. “There are many other playas in the American south-west,” says Bennett. This means there could be millions of other fossilised human trackways out there, waiting to tell their ancient stories of what life was like in the deep past. ▮

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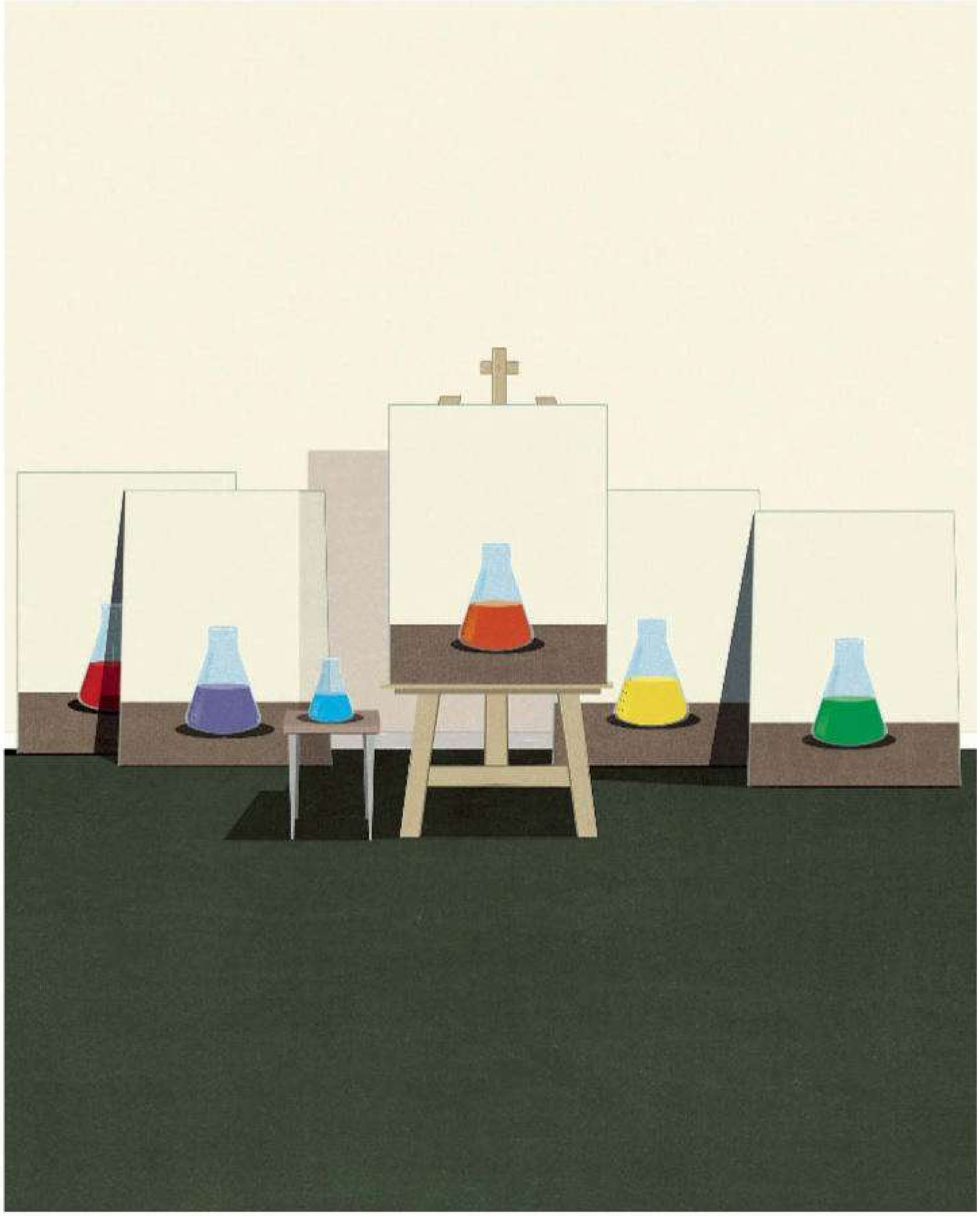


ANDREA UCINI

Failure to replicate

Some scientific studies don't stand up to testing and the problem may be getting worse. What is being done to fix it, asks **Clare Wilson**

I HAVE a confession to make: some of the articles that have appeared in *New Scientist*, including ones I have written, are wrong. Not because we deliberately misled you. No, our reports were based on research by respected scientists at top universities, published in peer-reviewed journals. Yet, despite meeting all the normal standards of credibility, some findings turned out to be false.

Science is in the throes of what is sometimes called the replication crisis, so named because a big hint that a scientific study is wrong is when other teams try to repeat it and get a different result. While some fields, such as psychology, initially seemed more liable than others to generate such "fake news", almost every area of science has since come under suspicion. An entire field of genetics has even turned out to be nothing but a mirage. Of course, we should expect testing to overturn some findings. The replication crisis, though, stems from wholesale flaws baked into the systems and institutions that support scientific research, which not only permit bad scientific practices, but actually encourage them. And, if anything, things have been getting worse over the past few decades.

Yet as awareness of the problem has grown, so have efforts to tackle it. So, how are these opposing forces faring? Will the efforts to combat fake science succeed? And how can you know if the research you read about in *New Scientist* and elsewhere will ever make it out of the lab and start working in the real world?

It is hard to pinpoint when the replication crisis began, but many people got their first inkling of it in 2011. That year, three things happened to ring alarm bells. First, a study was published that claimed to demonstrate psychic abilities. Some people apparently experienced improvements to their memory of word lists if they were given reminders after being tested. In other words, they were seemingly predicting the future. Later that year, a paper showed how easy it is to get invalid positive results. The key is "cherry-picking", producing lots of data and only using the figures that confirm your hypothesis, a practice also sometimes called p-hacking, after one of the terms in a commonly used statistical technique. A third blow was the brewing scandal over Dutch psychologist Diederik Stapel, who was caught simply making up results. This showed that the much-vaunted journal peer-review system – where journals ask experts in a field to decide whether a paper should be accepted – is no guarantee that only good science gets published.

"That was the year that psychology had this wake-up call," says psychologist Amy Orben at the University of Cambridge. What's more, there were growing rumblings that some seminal psychology results were unreliable. In 2012, researchers failed to replicate the finding that people exposed to stereotypes of ageing will walk more slowly when leaving the lab. The original experiment was a key result in the field of "priming", the idea that people's behaviour is affected by unconscious cues. Failure to replicate was also the undoing of another textbook finding, that we can "use up" our willpower, so if we are trying to resist tempting food, we find it harder to persevere with a mental task. Both these once-influential ideas have now fallen into disrepute.

For some science journalists like myself, these U-turns and the ensuing rows were fascinating, but not that concerning. Psychology has long been seen as less rigorous than the "harder" life sciences, like medicine or cell biology, mainly because human behaviour is so complex, making it difficult to measure and theorise about. But I was being too complacent. In the past decade, unreplicable scientific claims have emerged elsewhere – even in the physical sciences. It pains me to say it, but my own beat of medicine and the other life sciences seem among the most affected.

One of the worst hit areas is early stage biomedical research: laboratory studies of potential new drugs tested on animals or in cells grown in a dish. Such research is regularly taken up by pharmaceutical firms, who have the resources to turn it into new medicines. But it often turns out to be unsound. In 2011, an internal survey at drugs firm Bayer found that two-thirds of the leads from university research were failing to stand up when tested by company scientists. The next year, biotech firm Amgen investigated 53 landmark papers and found that only 1 in 10 could be replicated.

This, for me, was a real shocker. Many people understand that promising results in mice

MONTY RAKUSEN/GETTY IMAGES

"I hate to think how many stories I have written that gave people false hope"

> "Biotech firm Amgen investigated 53 landmark papers and found that only 1 in 10 could be replicated"

Medical research using cells (left) and animals (right) is particularly likely to be unreplicable

MAURO FERMARIELLO/SCIENCE PHOTO LIBRARY

may not translate to people. Before this, I didn't realise that results in mice may not even translate to other mice. Of course, not all university biomedical research is wrong – it has been the basis for many life-enhancing inventions, not least vaccines against covid-19. But I hate to think how many stories I have written that gave people false hope. Cancer research seems particularly hard hit, with a project published in 2021 confirming how few papers in this area can be replicated. All that waste of researchers' time, all those animals that died for nothing, not to mention the money, often raised by the public through fun runs and bake sales.

If you think the solution is to pay attention only to research in people, rather than in cells or animals, forget it. Several fields of medical research carried out in people also have reputations for unreliable findings. Take nutrition research, which aims to find out which foods are healthiest. It has become a standing joke that, depending on the day of the week, you can find studies telling you that a given food is bad for you or good. When I wrote an article about this in 2019, saying we should be sceptical of all nutrition studies, some colleagues thought I must be overstating the problems. If anything, my mistake was to confine my criticisms just to food research.

This state of affairs shouldn't really be surprising because the same causes of bad science in psychology are turning up in many places. Cherry-picking is increasingly possible because of the vast amounts of data generated in research these days, as a result of greater computing power to store and analyse it.

Noisy numbers

The more complex the science, the more data you get – like in brain scanning. Despite producing compelling images showing different parts of the brain "lighting up" in response to different stimuli, what actually comes out of an fMRI scanner is a mass of numbers. Researchers must then work out changes in brain activity from changes in blood flow, while factoring in multiple other variables. "We have to remove all of the noise in the scanner, noise in the way that our body's responding… and tens of other complications," says neuroscientist Cassandra Gould van Praag at the University of Oxford.

Initial brain scanning studies used too few human subjects to ensure that real patterns in the data stood out from the noise. Matters came to a head in 2009 with a study apparently showing that pictures of humans in emotional situations could trigger neural activity in a dead Atlantic salmon. The researchers had used the fish to test that their scanner worked, but then wrote up the faux "study" to show how easy it is to get false results. "That was an important message," says Gould van Praag.

But MRI researchers still have problems. A bombshell study found last month that research on links between the brain's structure or function and complex mental traits – such as cognitive abilities or risk of depression – would need thousands of participants. The average number of people scanned is 23.

Another way that the scientific record gets distorted is publication bias: studies that find a positive result are more likely to be published than those that don't. It isn't just scientists who tend to brush negative results under the carpet – so do editors and peer reviewers of journals. A less-talked-about kind of publication bias is the preference for headline-generating results. If you think journal editors should be above caring whether their papers are exciting, think again. The publishing industry has a ranking system called impact factors to indicate a journal's kudos. Impact factors are based on how many times each journal's papers have been cited in other papers. So "groundbreaking" research that gets more citations is highly prized.

The lure of fame has probably tempted some into bad science, but over recent years, the pressures have grown on scientists to produce as many papers in high-ranking journals as they can. One contributor to this ethos, sometimes known as publish or perish, is the increasingly competitive nature of academia, with growing numbers of junior researchers competing for limited jobs.

Its foundation is the way academic success is measured. Universities and the bodies that fund research – usually governments or medical charities – want to assess scientists' performance. That is hard, so they ask scientists how many papers they have published and what the journal impact factors were. "We are incentivised to publish and get grants," says psychologist Marcus Munafò at the University of Bristol, UK, who heads the UK Reproducibility Network, a group of researchers who are trying to improve things. "Those are the things that get us jobs, get us promoted. It doesn't matter if the findings are wrong." ›

KORHIL65/GETTY IMAGES

Cancer Research UK, which organises fundraising events like this one, has signed an agreement to help improve standards in cancer research

> "These problems collectively led to the rise and fall of an entire field of biology"

These problems collectively led to the rise and fall of an entire field of biology called candidate gene association studies. From the late 1990s, there were headline-grabbing claims that specific versions of certain genes active in the brain cause various mental health conditions. The field spawned hundreds of media headlines announcing that scientists had found the gene "for" depression, schizophrenia, aggression and so on. But then technology improved and researchers started doing more laborious studies involving hundreds of thousands of people, analysing not just individual genes but all the participants' DNA. These showed that common conditions like depression are affected by hundreds of gene variants, each with a tiny effect. None of the results from candidate gene studies stood up. "It was a lot of bunkum," says neurogeneticist Kevin Mitchell at Trinity College Dublin, Ireland.

Cycle of dysfunction

The more I researched this article, the more I came to despair. The problems are driven by three sectors that seem locked in a self-perpetuating cycle of dysfunction. Journals want flashy results to boost their impact factors and gain prestige. Funders award grants to people who have published in the most prestigious journals. And universities hire those who bring in the big grant money.

And yet there are efforts under way to break the cycle. They aren't being led, as you might expect, by the ancient and venerable institutions of science. In fact, change has been driven mainly by junior researchers trying to fix things from the bottom up. "These have been people working in their bedrooms, creating websites, running Twitter campaigns," says Orben, who does such work herself.

One approach is "preregistering", where researchers describe their hypothesis and their intended study on a website before they begin. It means a negative result can't just be ignored. With enough detail about the methods, it can also prevent cherry-picking. Some journals now let papers display a symbol to show that the study was preregistered. The Center for Open Science, a US grassroots organisation that tackles bad science, has created such a badge. It also offers two more badges indicating that researchers will share all their data and information on methods and materials, allowing others to check or replicate the study.

In a more radical step, a preregistered study can be sent to a journal before it is carried out, a system called registered reports. If peer reviewers OK it, the research gets published no matter what the results, further reducing the risk that negative studies get airbrushed from history. "The journal accepting the paper on the basis of its method rather than its results is transformative," says psychologist Stuart Ritchie at King's College London. "This is the best way to do science."

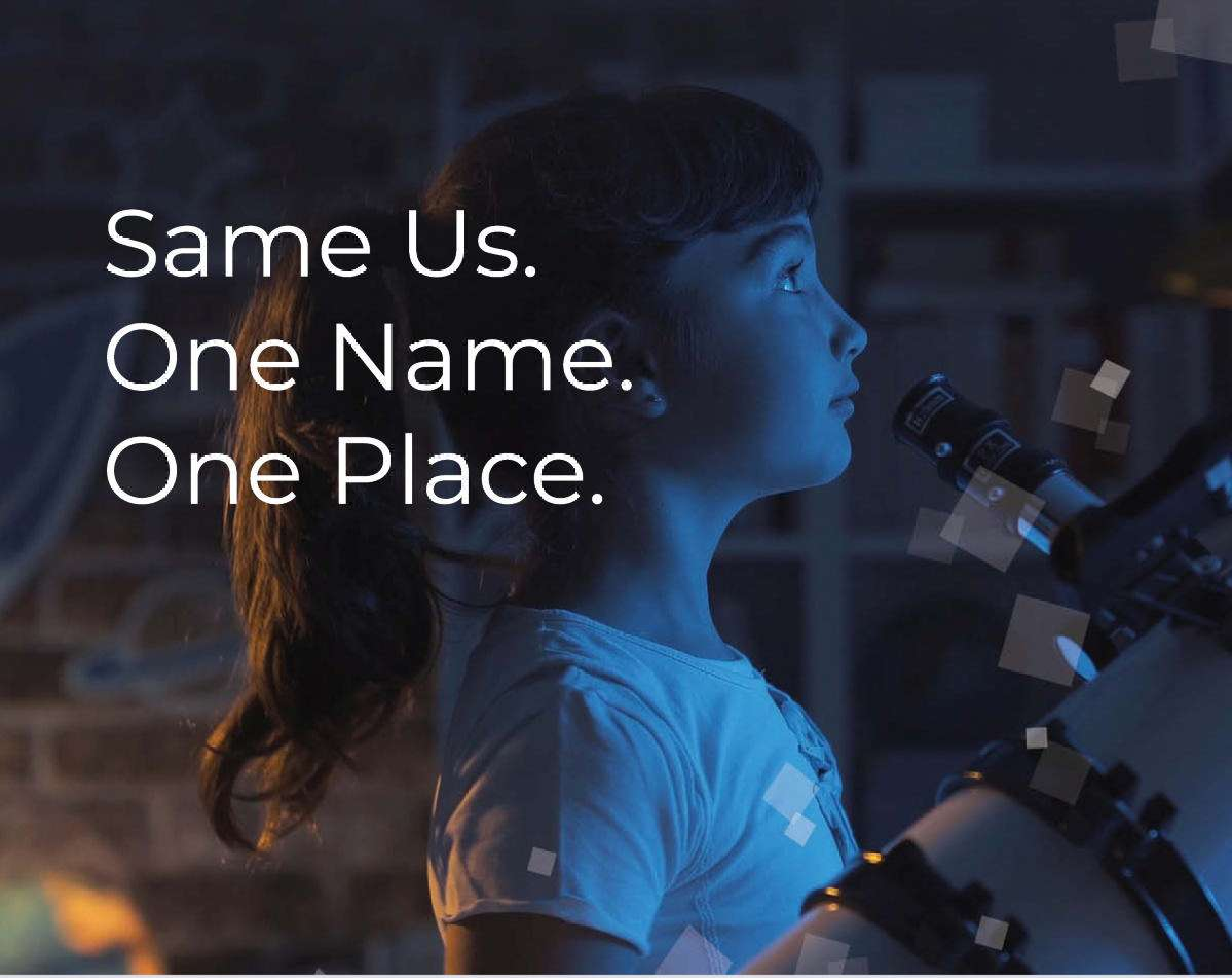
Currently, only a small fraction of papers are preregistered or submitted as registered reports. Perhaps unsurprisingly, progress seems fastest in the field of psychology. Nevertheless, I am excited about these practices, known collectively as open science. If they catch on more widely, it would be a simple way for anyone to judge which claims are most reliable.

Slowly, creakingly, there are signs that funding bodies are trying to address the problem too. The National Institutes of Health, the biggest funder of biomedical research in the US, says that from next year all grant recipients must share their data. UK Research and Innovation (UKRI), the umbrella body for the seven research councils, which fund most science in UK universities, has similar ambitions, although no start date yet. Speaking in February at an inquiry into reproducibility held by the House of Commons science and technology committee, UKRI chief executive Ottoline Leyser really seemed to get the problems – and she is hugely influential.

Meanwhile, an international agreement called the San Francisco Declaration on Research Assessment asks universities and funders to pledge not to use journal impact factors in hiring, promotion or grant decisions. Many heads of universities have signed up, but it remains to be seen whether this will influence middle managers who make hiring decisions, says Orben. Another signatory is Cancer Research UK, the world's largest charitable funder of cancer research. So maybe those fun runs are worth it after all.

I asked everyone I interviewed for this article how much progress has been made in fixing bad science since those alarm bells started ringing more than a decade ago. Nearly all say that a good start has been made – but there is a long way to go. Munafò puts it slightly differently. "There's a saying that revolutions happen very slowly and then all at once," he says. "It feels like we're getting to the all-at-once stage where real change is actually happening." Let's hope he is right. ▮

Clare Wilson is a biomedical reporter at New Scientist. Follow her on Twitter @ClareWilsonMed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The back pages

Puzzles
Try our crossword, quick quiz and logic puzzle p53

***Almost* the last word**
Why does some music evoke certain emotions? p54

Tom Gauld for *New Scientist*
A cartoonist's take on the world p55

Feedback
Quantum hairdos and mattress turning: the week in weird p56

Twisteddoodles for *New Scientist*
Picturing the lighter side of life p56

Citizen science

Unlock the secrets of letters

Spot visual patterns in the world's written languages to boost the science of graphical communication, says **Layal Liverpool**

Layal Liverpool is a science journalist based in Berlin. She believes everyone can be a scientist, including you. @layallivs

What you need

Access to the Glyph website at glyph.shh.mpg.de

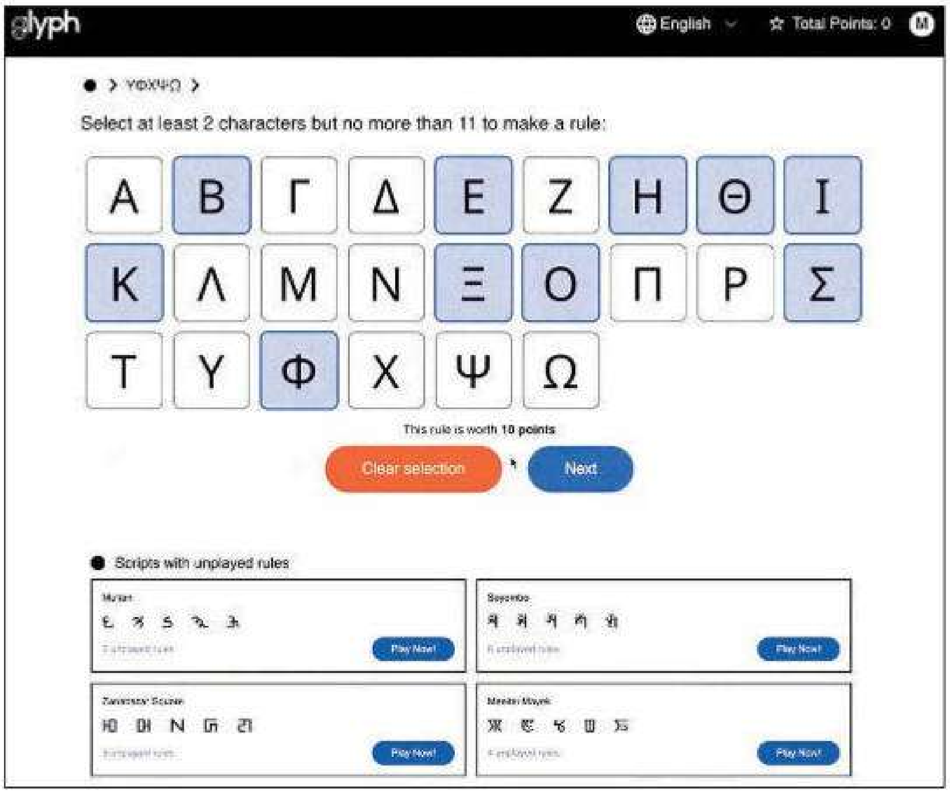
STOP reading for a moment and instead take a closer look at the letters that make up each of the words in this sentence. What shapes do the different letters in the alphabet have in common? What makes each letter unique?

Yoolim Kim at Harvard University and her colleagues at the Max Planck Institute for the Science of Human History in Germany are trying to answer these questions. They are interested in analysing writing and graphical communication systems from around the world (see picture). You can help them by taking part in the Glyph citizen science project.

In the Glyph online game, you will be presented with a set of characters – such as the letters in this clause – and asked to select as many characters as possible based on simple rules you create yourself. For instance, I could select "h", "i", "l", "n", "r", "t" and "u" from the clause in the previous sentence, because those letters all have vertical lines in them.

The Glyph research team is using the data generated by volunteers to identify the building blocks of letters from more than 40 different writing systems. The more rules you create as you play, the more points you gain and the more scripts you will unlock to analyse. You will get bonus points for creating unique rules.

The researchers hope that the data from players will help them to understand the relationships between letters within writing systems in terms of how people perceive them, as well as how those letters are pronounced in spoken language.



Select at least 2 characters but no more than 11 to make a rule:

This rule is worth **10 points**

MPI-SHH/PSL SCRIPTA

"Writing for us is a lens through which we can look at the bigger question of how sound and form is linked in a meaningful way," says Kim. For instance, it will be possible to explore whether letters that sound similar when spoken are also perceived by people as having similar shapes or features in their written form, she says.

Preliminary results from the Glyph project suggest that people often converge on similar sets of rules for classifying letters. "You might describe it as left to right symmetry, or I might describe it as vertical or horizontal lines – but, conceptually, you and I have kind of identified the same thing," says Kim.

Spotting these sorts of shared patterns in how people perceive letters could aid the development of more effective methods for teaching people how to read and write, she says.

Learning how people combine letters to form words is also of interest to linguists. "Word games like Wordle are becoming very popular, for example, and a lot of researchers are after that data, because that probably contains tonnes of insights," says Kim.

As with Wordle, I found Glyph to be an excellent workout for my brain. Visit the Glyph website to join in the fun and boost the research. ▮

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Citizen science appears every four weeks

Next week

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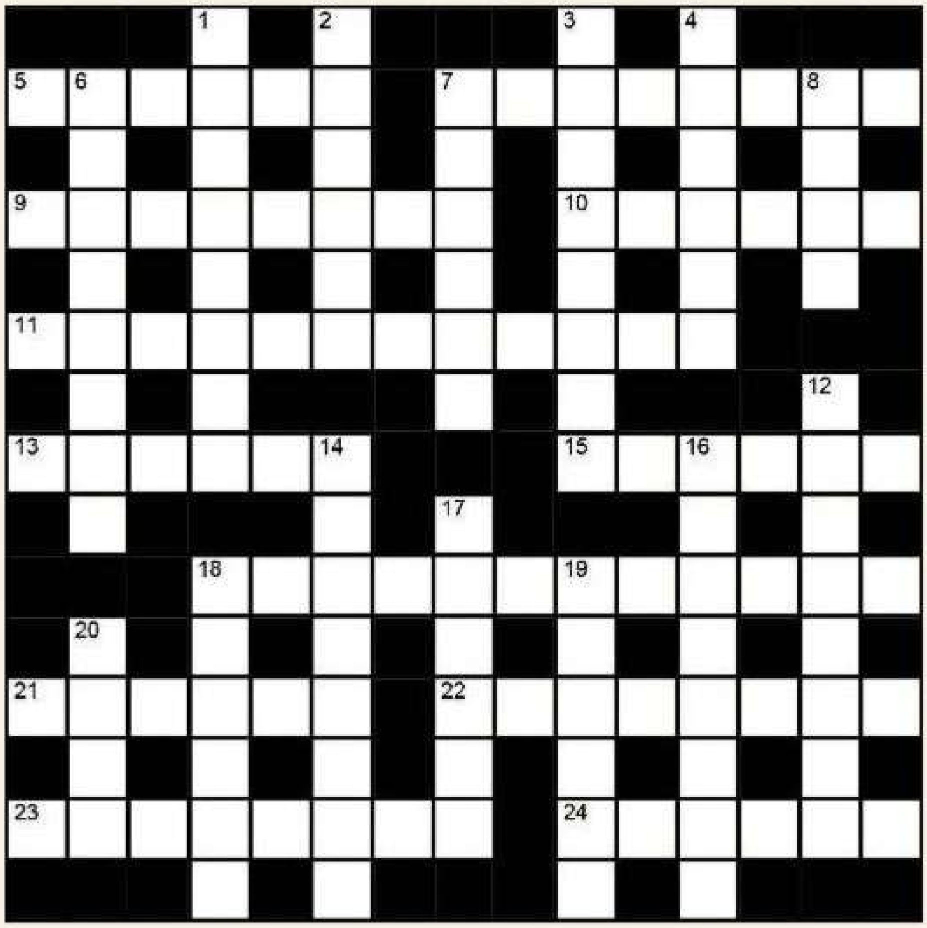
Quick crossword #105 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

5 Maternal parent (6)
7 Groove in the upper lip (8)
9 Flowering plant also known as leadwort (8)
10 Axilla; oxter (6)
11 Sweat (12)
13 Max ___, Nobel prizewinning German physicist (6)
15 Impact hole – Tycho or Humboldt, perhaps (6)
18 Hungarian-American theoretical physicist known as "the father of the hydrogen bomb" (6,6)
21 Heart operation (6)
22 Iron-bearing sedimentary rock (8)
23 Prepuce (8)
24 Ocular scale found on snakes and many lizards (3,3)

DOWN

1 Particle formed of a strange quark and a strange antiquark (3-5)
2 Asian mountain sheep (6)
3 Ascorbic acid (7,1)
4 Pollen-producing organ of a flower (6)
6 Points of access to petroleum reserves (3,5)
7 Fluoxetine brand (6)
8 K, s, kg or m, say (4)
12 Progressive impairment of thinking and behaviour (8)
14 Japanese industrial corporation (8)
16 Hexagonal driver for bolts and screws (5,3)
17 p^+ (6)
18 Mineralised tooth surface (6)
19 Heart (informally) (6)
20 Misprint (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #146

1 Young animals that are hatched or born in a relatively undeveloped state and require care from their parents are known as what?

2 In astronomy, what does SSSB stand for?

3 Which Dutch scientist was the first person to observe bacteria and protozoa?

4 How many vertices does an icosahedron have?

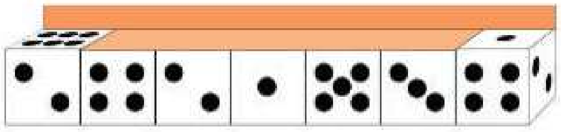
5 The composite organism formed from the mutual relationship between fungi and algae or cyanobacteria is known as what?

Answers on page 55

Puzzle

set by Steve Wain

#162 Hidden faces



While window-shopping at a toy store, my partner and I came across a set of dice that was partially obscured at the back of the shop's display.

My partner took one look and bet me that I couldn't tell them what the sum of all the touching faces between the dice would be. I accepted and gave the correct answer. What was it?

Solution next week

Mood music

I am a big fan of classical music. Why does some music evoke certain emotions in the brain, even if it doesn't have any lyrics?

Gabriel Byczynski
Birmingham, UK

Music is a wide-reaching stimulus for humans, activating many regions of our brain. Even without lyrics, the melodies and rhythms of music have a big impact.

When listening to classical music, we may feel relaxed when a chord meets its climax, happy when the pitches of notes remind us of emotions or old memories and scared as the brain's amygdala region becomes active and releases stress and anxiety hormones.

Talia Morris
Cape Tribulation, Queensland, Australia

I think that, in some societies at least, people are trained to associate certain emotions with particular types of music by movies and television, because of the formulaic way it is frequently used in them: violins for sad scenes; loud, dramatic orchestral music with lots of percussion for battle scenes; etc. It would be interesting to see whether people with limited exposure to such media have similar emotional responses to the same music.

> **"Spoken words can be less informative than the music in our message. 'Come here' could be seductive or threatening"**

STEVE BLY/ALAMY

Hummingbirds flap their wings many times a second, but does that make them out of breath?

This week's new questions

Breathless birds **Do birds ever get out of breath?** ***Geoffrey Cox**, Rotorua, New Zealand*

Placebo power **What is it exactly that provides the healing effect of a placebo treatment?** ***Richard Watts**, Vancouver, British Columbia, Canada*

Betty Tijms & Jochum van't Hooft
Amsterdam, the Netherlands

Music possibly predates language as we know it today. Our pre-linguistic hominin ancestors may have used musical features, such as pitch, rhythm and timbre, to communicate intentions and transmit emotions. From an evolutionary point of view, these musical features carry an emotional value that may be essential for survival. This would explain why music without lyrics can evoke strong emotions.

Daniel Forth
Falkirk, UK

Music has tone and rhythm, much like the human voice. We use this to interpret a speaker's emotions, not just their words. This is why *Dos Oruguitas* is so effective at provoking tears in the English version of the Disney film *Encanto*, even if you don't speak Spanish.

Sara Pascoe
Bournemouth, Dorset, UK

The musicality of vocalisation is the real communicator across cultures, species and the world, not the words. The neuroscience of "affective prosody", the musicality of spoken language, reveals the circuits involved: these are parts of the brain known to underpin emotional processing and perception, including the thalamus, the basal ganglia and the cingulate, temporal and frontal cortices.

Just as hearing verbal threats or loving invitations evoke different responses in us, when songs use similar musicality, our brains receive and perceive them similarly. Film and TV composers utilise our reactions to these sounds. Think of how different the soundtracks are for comedy films compared with horror ones.

The words we speak can be less informative and reliable than the music in our message. "Come here..." can be anything from seductive to threatening, and telling a pet it is "a bad dog" in the affectionate tones used for "good doggy" demonstrates the power of prosody.

Bryn Glover
Ripon, North Yorkshire, UK

I would like to respond to this question with a plea rather than an answer.

I was fortunate to have been taught to appreciate music at school, learning first how to listen to *Má Vlast* by Bedřich Smetana, then taking in *Fingal's Cave* by Felix Mendelssohn and Antonín Dvořák's "New World" symphony. But this appreciation ended abruptly when experiments in physics classes came to the fore in my education.

I found myself challenging the "silliness", as I saw it, of absorbing uncritically what were no more than vibrations of the air. I regret to say that this state of affairs persisted for some years. Later in life, I started making violins as a hobby and switched back to an uncritical enjoyment of the beauty of their output, bitterly regretting the lost years.

I would suggest that the person who posed this question should end their attempt to analyse what is going on, and instead lie back and allow those glorious noises to continue to inspire them.

Feed the world

How many humans would be alive today if agriculture had never been invented?

Hillary Shaw
Author of The Consuming Geographies of Food
Newport, Shropshire, UK

Without agriculture, as a hunter-gatherer species, we would (like any other animal) breed up to the limit the land could support and then suffer culls by starvation

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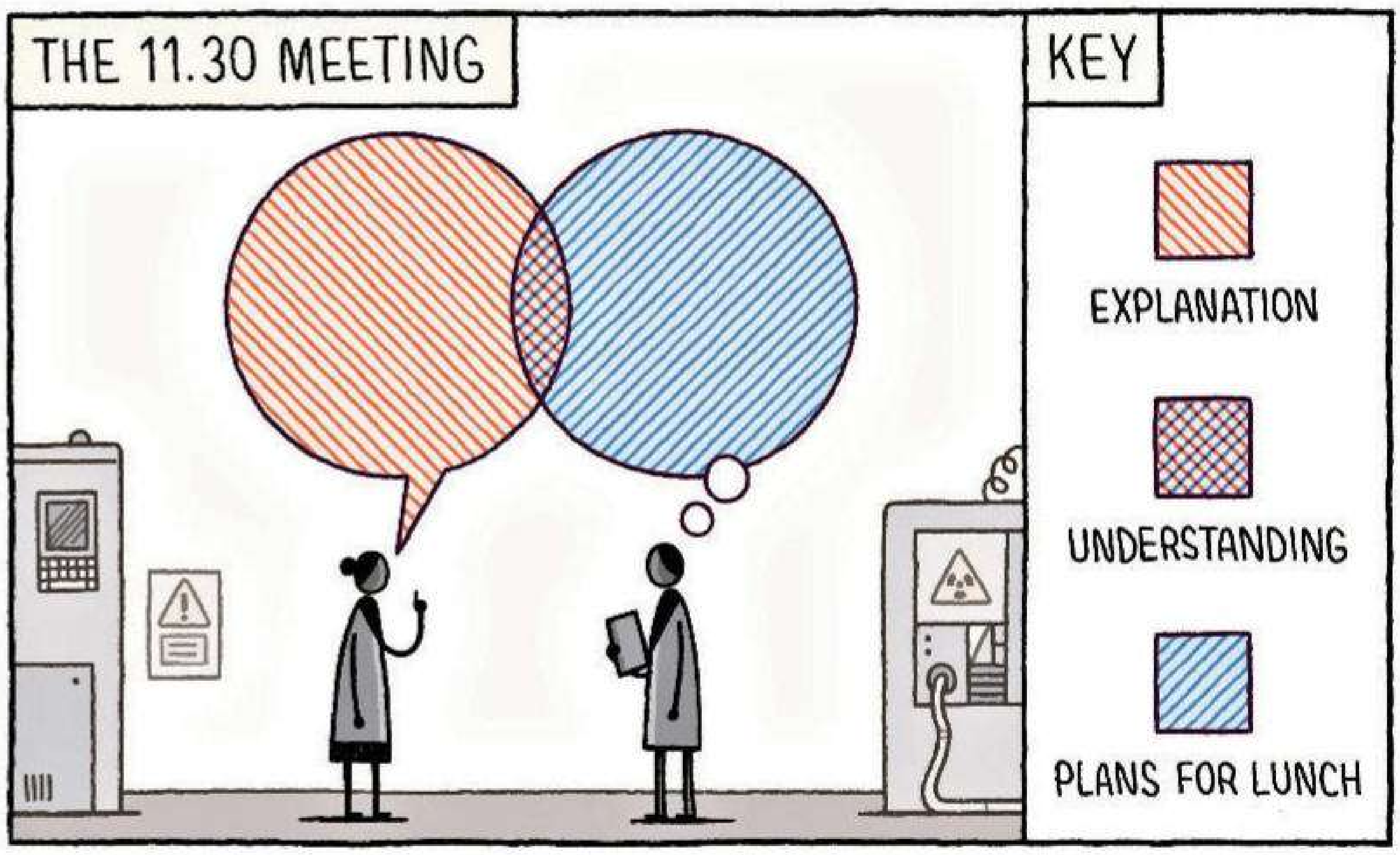
Tom Gauld
for New Scientist



and disease to maintain this level.

Fertile land, like most of Europe, might support one hunter-gatherer per 26 square kilometres, but this falls to as low as one per 250 km² in the Australian desert, as calculated by Ian Simmons in his book *Changing the Face of the Earth*.

The World Bank estimates that 37 per cent of Earth can be classed as agricultural land, but through forest clearance, agriculture has probably been responsible for some degradation and desertification of formerly fertile lands. So let's say that, in a pre-scientific age, 50 per cent of Earth's 500-million-km² land area (minus Antarctica) would be "fertile". Using Simmons's figures, we then have a non-agricultural population of around 10 million people.

Mike Follows
Sutton Coldfield, West Midlands, UK

The short answer is about 10 million. Growing crops increases the population that can be sustained by the same area of land. This is why the earliest civilisations developed alongside major rivers, where the water could also be used to irrigate the ground. This led to a population explosion to maybe 50 million people, concentrated in Mesopotamia, ancient Egypt and the Indus valley.

Agriculture has increased the proportion of biomass that is edible. This has been enhanced by the use of insecticides, herbicides and artificial fertiliser. Yields have also been enhanced by plant and animal breeding, and factory farms increase them still further. The land available for farming has been expanded by irrigating deserts and draining swamps.

But the population increase to nearly 8 billion wouldn't have been possible without the economic systems and transport infrastructure that allows food to be moved from place to place.

> **"Imagine if agriculture were uninvented and we had to draw lots to inhabit this new world. We would have odds of about 1 in 800"**

Imagine if agriculture were uninvented and we had to draw lots to decide who would inhabit this new world. Each of us would have odds of about 1 in 800. Given that we are bending nature to our will to extract 800 times as much food as it would yield naturally, we surely have a responsibility not to waste what we produce.

Peter Sutton
Guildford, Surrey, UK

The most likely answer is something between 2 million and 20 million, as without agriculture, we would be restricted to a semi-nomadic lifestyle.

What is certain is that in such a world, with no domesticated livestock, there would be millions more elephants and hundreds of thousands more lions, tigers and whales. This would be fantastic. However, it is most unlikely that we would be reading about it in *New Scientist*. ▮

Answers

Quick quiz #146
Answers

1 Altricial
2 Small solar system body, defined as objects that aren't planets, dwarf planets or natural satellites
3 Antonie van Leeuwenhoek
4 12
5 Lichen

Cryptic Crossword #80 *Answers*

ACROSS 1 Edmond Halley, **9** Taffeta, **10** Ionic, **11** Xenobots, **12** Psst, **14** Meteor, **15** Season, **18** Odds, **20** DeepMind, **23** Slake, **24** Gyrated, **25** Transcendent

DOWN 2 Defunct, **3** Open book, **4** Dearth, **5** Aril, **6** Lends, **7** Yucatan, **8** Styx, **13** Tempered, **14** Moonset, **16** Stilton, **17** Beagle, **19** Drama, **21** Dodo, **22** Cels

---

#161 Reduction deduction
Solution

Lionel's birthday is 25 May.

365 is a product of two prime numbers: 5 and 73. So every fifth day and every 73rd day would result in a reducible fraction if we write them as day of year/365.

There are two points in the year on which two consecutive dates given as fractions are reducible. These are the 145th and 146th days (reducible to 29/73 and 2/5), and the 219th and 220th days (reducible to 3/5 and 44/73).

In the first pair, the second day contains the smaller numbers, so that must be the correct pair, and thus Lionel's birthday is on the 145th day, or 25 May.

Quantum 'do

Feedback was relieved to read elsewhere in this august rag recently that black holes aren't bald, featureless entities with an ever-expanding waistline, but have a bubbling frizziness around their outskirts known in some quarters as "quantum hair" (26 March, p 10). We are relieved not just because the middle-aged look has never been fashionable, but also because this promises a resolution to Stephen Hawking's black hole information paradox, an unsolvable conundrum in fundamental physics that is also getting depressingly middle-aged.

And developing that new, fresh look is as simple as popping a daily pill, as Suzie Shrubb points out. She forwards us – with an eye on the black holes, we hope, not us – details of Quantum Nutrition Labs' Quantum Hair, Skin, Nails capsules. These promise "Bioavailable Solubilized Keratin for Quantum-State Support for The Skin, Hair and Nails", something we find merits the capitals, even as we wonder with Suzie whether the quantum state bit expresses some uncertainty about the product's efficacy. Still, as she reasonably points out, you will only ever know after you have looked in the box.

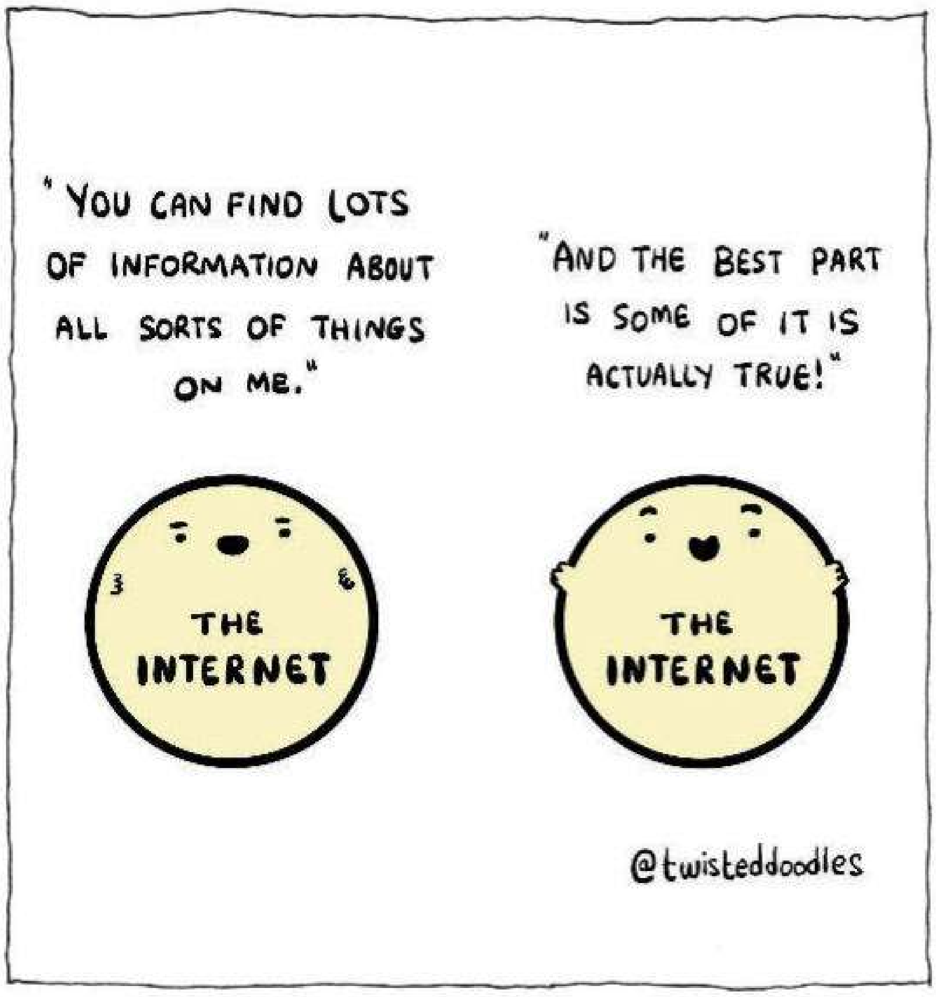
For timeless style right from big bang to heat death, we can also recommend Zotos's Quantum Classic Body hair perm, an acid perm that "creates soft, supportive body and supportive waves for a 'non-permed' look". Coming soon to an event horizon near you.

Lose friends, stay healthy

Epidemiology news, as Korean Vaccine Society vice president Ma Sang-hyuk announces that if you haven't had the dreaded lurgy yet, it is because you have no friends. "Adults who have not yet been infected with COVID-19 are those who have interpersonal problems," he is reported to have written on Facebook – comments that seem to have won him few friends, and so perhaps a degree of protection, as they were subsequently hastily deleted.

Feedback's experience suggests you hardly need be in contact with anyone to catch the latest variant nasty. Certainly, we have been trying to build up immunity to infection through social isolation for years, and it didn't work for us.

Twisteddoodles *for New Scientist*


"YOU CAN FIND LOTS OF INFORMATION ABOUT ALL SORTS OF THINGS ON ME."
THE INTERNET
"AND THE BEST PART IS SOME OF IT IS ACTUALLY TRUE!"
THE INTERNET
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Not a prayer

Also strangely transient is Eternal Prayer, a website that briefly offered to mint the prayers of the devout as non-fungible tokens for a small consideration of real-world money.

As deities move in mysterious ways, it seems not unreasonable to us to desire non-falsifiable records of contracts entered into, even if, dinosaur that we are, we prefer the tablets of stone thing. But with the site now defunct, our eternal, fruitless search for meaning in the blockchain continues.

A mattress for all seasons

Bringing us back down to earth, Richard Bartlett notes that the care instructions for his John Lewis mattress include the advice "No turning required, rotate with the seasons." "Perhaps I should not move it at all relative to the bed but simply allow the mattress to orbit the sun?" he asks. We consider this a wise starting point for anyone invested in a good night's sleep. Or you could try the alternative interpretation of rotating yourself with the seasons, and see where that lands you.

Come shapely bombs

Feedback is a fan of what novelist Anthony Burgess termed the *"arresting opening"*. A frisson passes through us as we peruse an article from The *Washington Post* sent in by Mike Shefler of Gibsonia, Pennsylvania, among others. "Near steep vineyards of riesling grapes, in an underground vault at an air force base in western Germany, sits an American nuclear bomb. More than one of them, actually," we read. "Each bomb is about the length of two refrigerators laid down end to end and as heavy as the average adult male musk ox. The bombs are slender and pointy and a little more than a foot wide." We join Mike in a waking reverie on the slender pointiness of the adult male musk ox, and feel the mind-expanding power of quality journalism.

Naughty corner

"I know it's a bad habit", sighs our man with the laser sight Jeff Hecht, bringing us to our senses again as he forwards us a briefing from the Government Matters website on high-energy laser weapons. We read that the US Department of Defense plans to deploy a 300-kilowatt laser for testing this November and to develop megawatt lasers effective against some ballistic missiles within a few years. The progress is "really exciting", says retired US Air Force colonel and director of the Mitchell Institute for Aerospace Studies, Mark Gunzinger.

From beyond the jrave

Stephen Wilhite, creator of the GIF, an invention that has done much to remove the need for words in internet communication, has died. We are commemorating him by playing our favourite GIF of UK politician Liz Truss pronouncing the words "pork markets" with relish. No reason, which is the point.

Sadly, there is no chance of reanimation for Wilhite, but his legacy has brought joy to millions, as well as a lovely debate about pronunciation. In lieu of words on accepting the 2013 Webby Award for lifetime achievement, Wilhite played a five-word animated gif: "IT'S PRONOUNCED "JIF" NOT "GIF". Somehow, however often you repeat that one, it's not sticking. ▮

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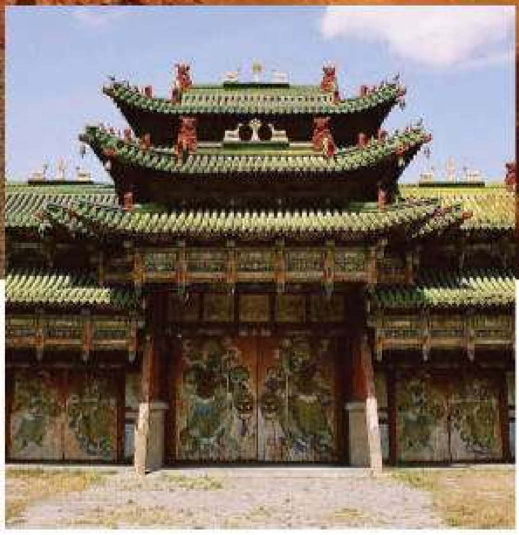
- Explore the legendary Flaming Cliffs, red sandstone formations stretching over 3 kilometres in width, where hundreds of dinosaur fossils have been discovered over the course of the last century.
- Follow in the footsteps of legendary American explorer Roy Chapmen Andrews who discovered the first dinosaur eggs that the world had ever seen nearly a 100 years ago.
- Fly over a vast steppe to Dalanzadagad. This is the gateway to the Gobi Desert, comprised of mountains, sand dunes and fossil beds.
- Visit the Mongolian Institute of Palaeontology and Geology and receive a report on your fieldwork. Approximately 8 weeks later you will be issued with a final trip report from the institute.
- Tour the Zanabazar Fine Arts Museum, named in honour of the renowned 17th century artist and politician, who was also the first Buddhist leader of Mongolia.
- Visit to Gandan Monastery where you will meet the 26-metre-tall standing Buddha and visit monks in service.
- Marvel at the National History Museum in Ulaanbaatar for an excellent overview of Mongolia's history and culture.



PETER OXFORD

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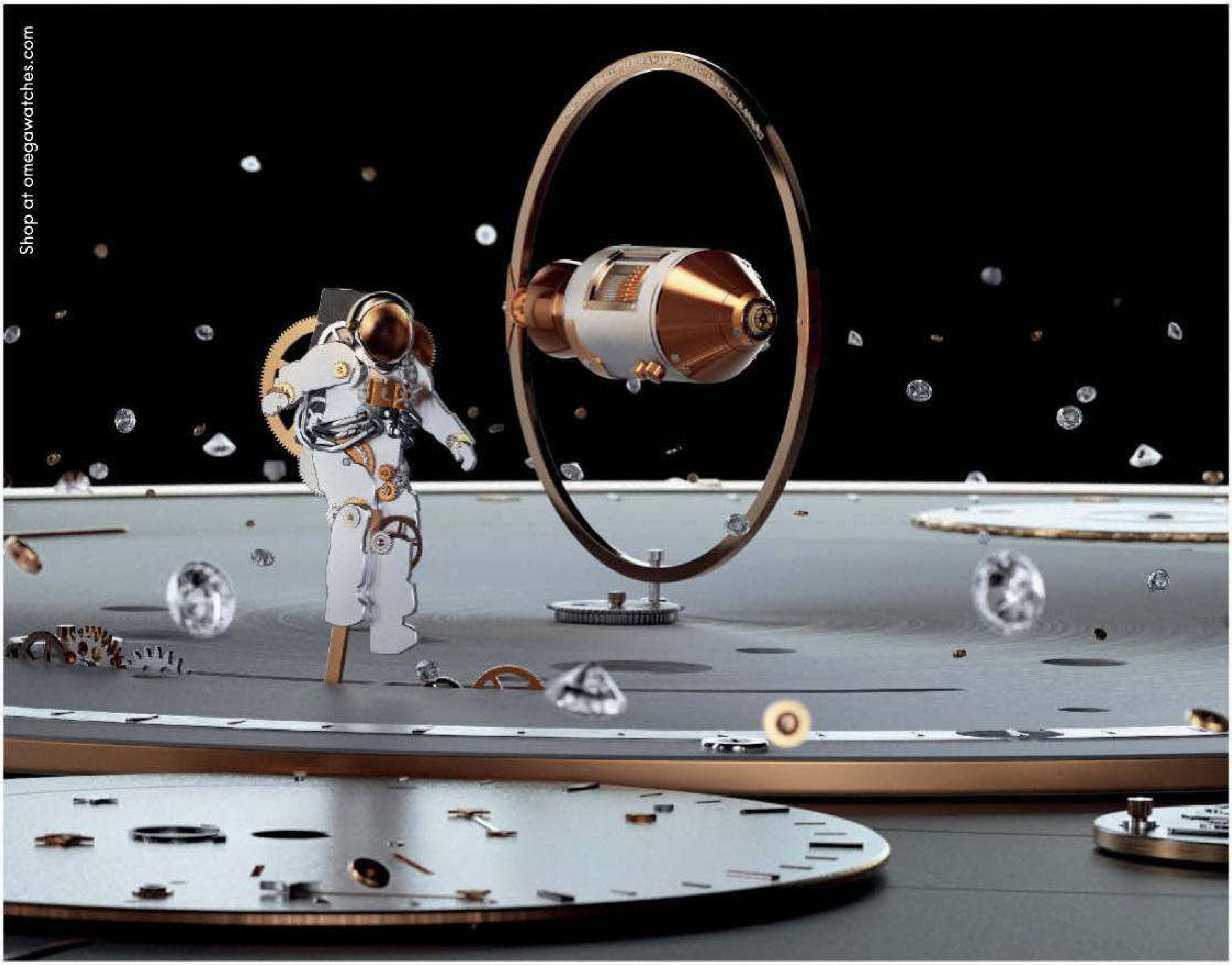

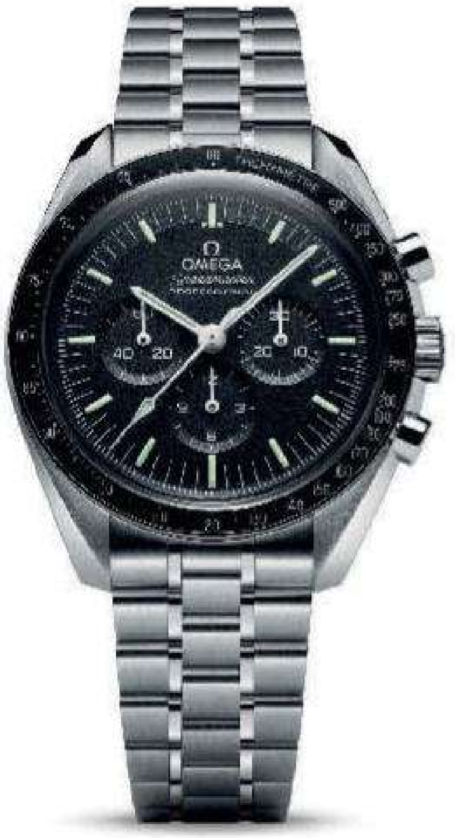

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